CATALYTIC OXIDATION TECHNOLOGY TRANSFER PROGRAM

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
16 NOV 2004	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Catalytic Oxidation Technology Transfer Program	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Research and Technology Directorate Edgewood Chemical Biological Center US Army, Research Development and Engineering Command**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001849, 2004 Scientific Conference on Chemical and Biological Defense Research. Held in Hunt Valley, Maryland on 15-17 November 2004 . , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**42**	

Overall Objective

Guild Associates, Inc.

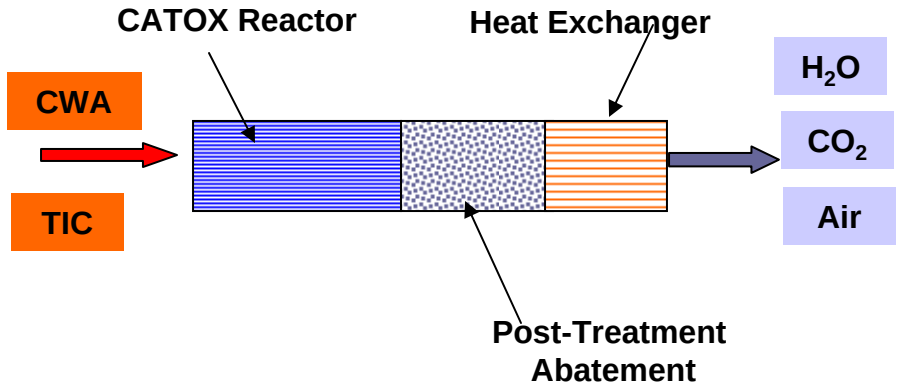
- Design, construct and evaluate a catalytic air purification system for collective protection applications
  - Demonstrate Broader Protection of Catalytic versus Single Pass Filtration Technology
  - Optimize Power, Weight and Size of Catalytic Process

Approach

Guild Associates, Inc.

-Incorporate commercial/newly developed catalysts for chemical, biological and TICs destruction (leverage w/ Advanced Adsorbents Program)

-Establish design relationships for predicting system size and energy requirements for potential applications



Program Leverage

Guild Associates, Inc.

DARPA Investment

TECHNOLOGY READINESS LEVELS

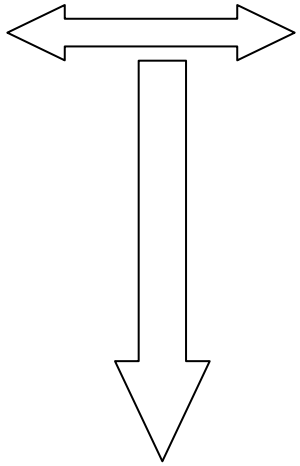
- identification and evaluation of acid gas abatement strategies

ECBC/INDUSTRY

COLLABORATION

LAB-SCALE TESTING (COMPONENT)

- evaluation of commercial catalysts



SYSTEM-SCALE TESTING

- evaluation and optimization of catalyst system components
- integration of system components
- determine size and energy requirements of scalable AP system

DARPA Investment

Guild Associates, Inc.

– **Objectives**

- **Technology maturity level/Technology readiness level**
- **Applicability/relevance to DoD CB Defense Acquisition Program**
- **Potential to mature for evaluation in field environment**
- **Availability of other funding to leverage Technology Transition investment**
- **Availability to government of data bases, methodology details, and design concepts**

Chemical delivery sensitivities

Guild Associates, Inc.

- Single pass filters have their capacity defined in terms of CT (conc x time).
- This is a misleading indicator for CATOX.
- CATOX challenges must be as close to the application's threat to account for performance sensitivities to:
  - # of attacks
  - Dosage per attack
  - Peak concentration
  - Frequency of attacks
- CATOX systems can succeed or fail for a given CT if any of these variables are changed.

Benefits

Guild Associates, Inc.

Current filter technology

- limited capacity for agents that are removed by chemical reaction and/or weakly adsorbed
- minimal protection versus several of the toxic industrial chemicals (TICs)
- prolonged environmental exposure has been shown to reduce the capacity of these filters for agents that are removed by chemical reaction

Catalytic oxidation

An alternative air purification technology

(1) broad and universal protection against the chem-bio threat,
(2) reduced logistics due to long operational life,
(3) greatly increased capacity for CB agents and TICs compared to current NBC collective protection technologies and
(4) lower energy costs relative to other regenerative filtration technologies.
(5) Catalytic oxidation is a destructive technology, converting CB agents and TICs to CO_2 (catalysts exist that are capable of decomposing nitrogen-containing compounds with minimum NOx formation), H_2O and haloacids (should halogens be associated with the parent compound).

Challenges

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- **Issues**
  - **Toxic By-products**
  - **Catalyst Stability**
  - **Energy**
  - **Post treatment**

- **State of the Art**
  - **High activity**
  - **Stable catalysts**
  - **NO_x, acid retention**
  - **Improved acid abatement technologies**

- **Mitigation of reaction product emissions**
- **Maximize heat recovery to minimize energy utilization**

Material Development

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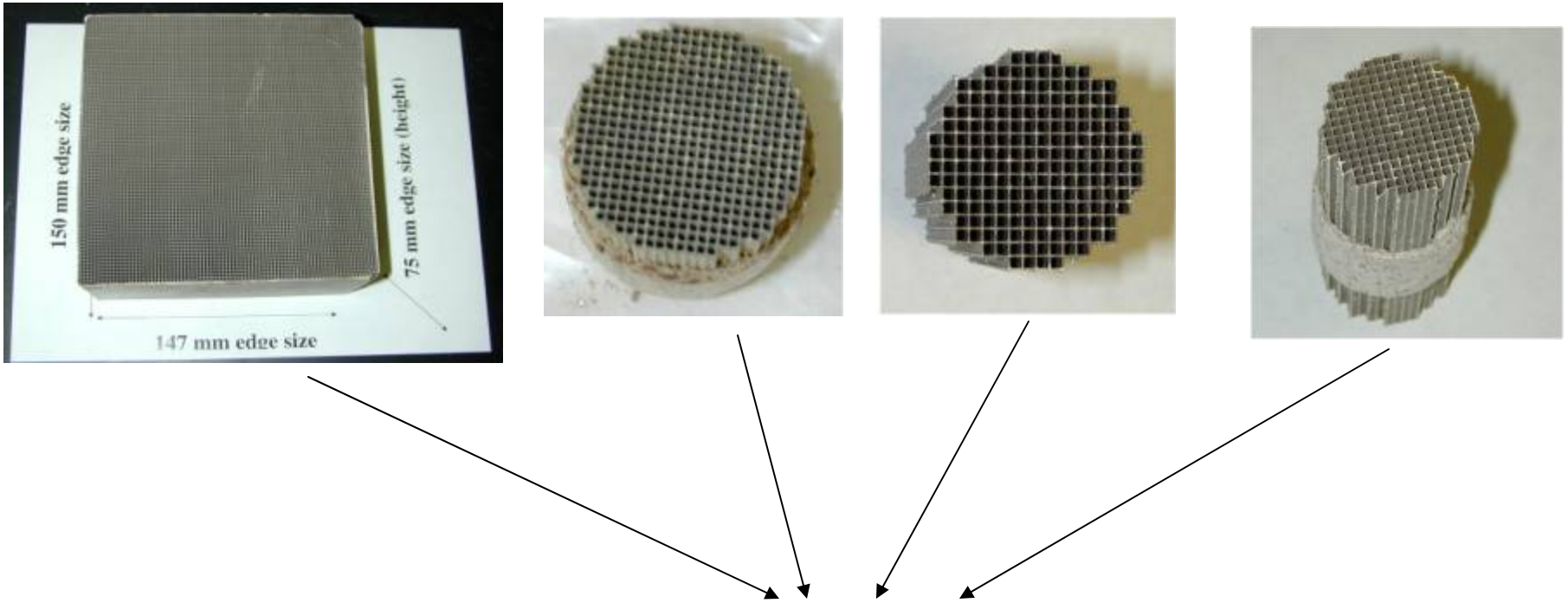
-Incorporate commercial/newly developed catalysts for chemical, biological and TICs destruction



Downselect (light-off curves and selectivity)

Monolithic Bed Catalyst Suppliers

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Manufacturer	Catalyst Designation	Cell Density
Engelhard Corporation	Engelhard Catalyst	200 Cells/in^2
United Emissions Catalyst	NB001-73-01	200 Cells/in^2
United Emissions Catalyst	NB001-73-02	200 Cells/in^2
Sud Chemie Prototech	LS02-03145	400 Cells/in^2
Sud Chemie Prototech	Misc-03144	400 Cells/in^2
Guild Associates	No-NO_x	400 Cells/in^2
Guild Associates	3X	400 Cells/in^2
Johnson Matthey	CatalyK6 Sample	400 Cells/in^2

Lab-scale results

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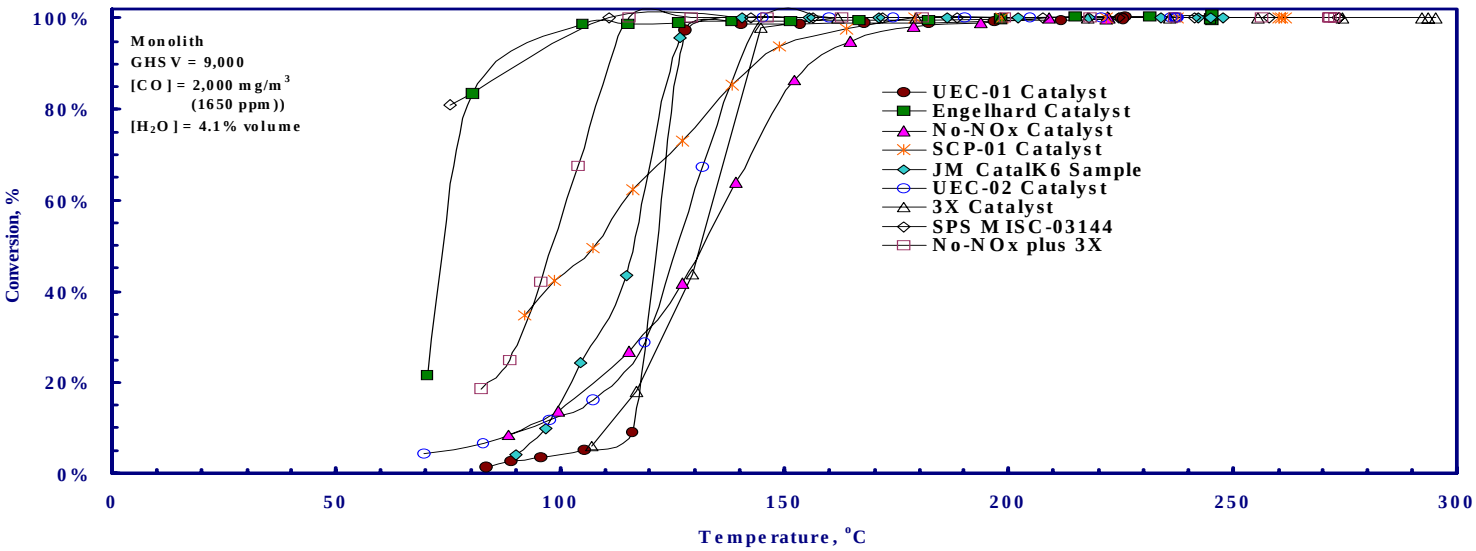
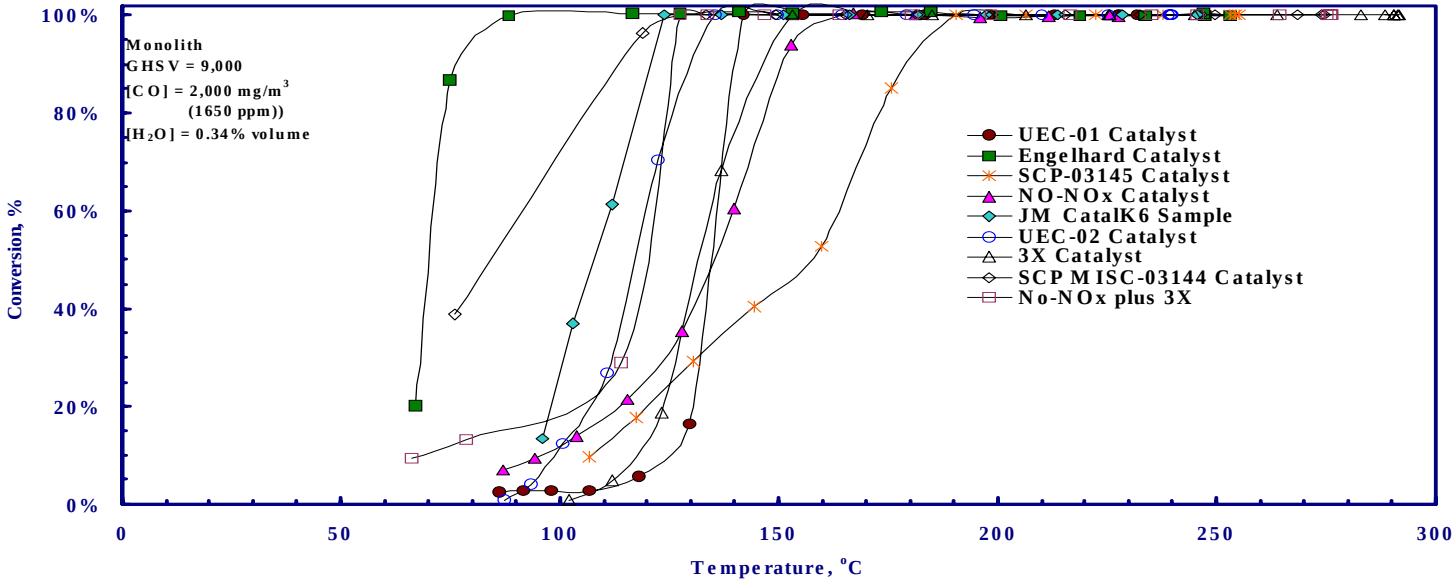
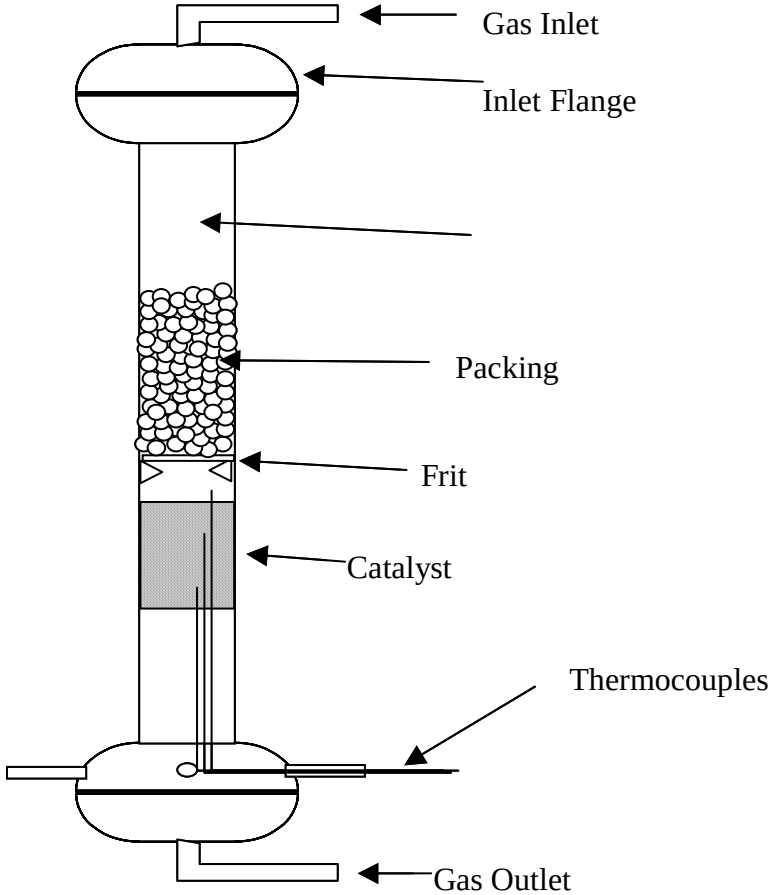
Catalyst oxidation of CO by catalytic materials under low and high humidity conditions (materials improvement)





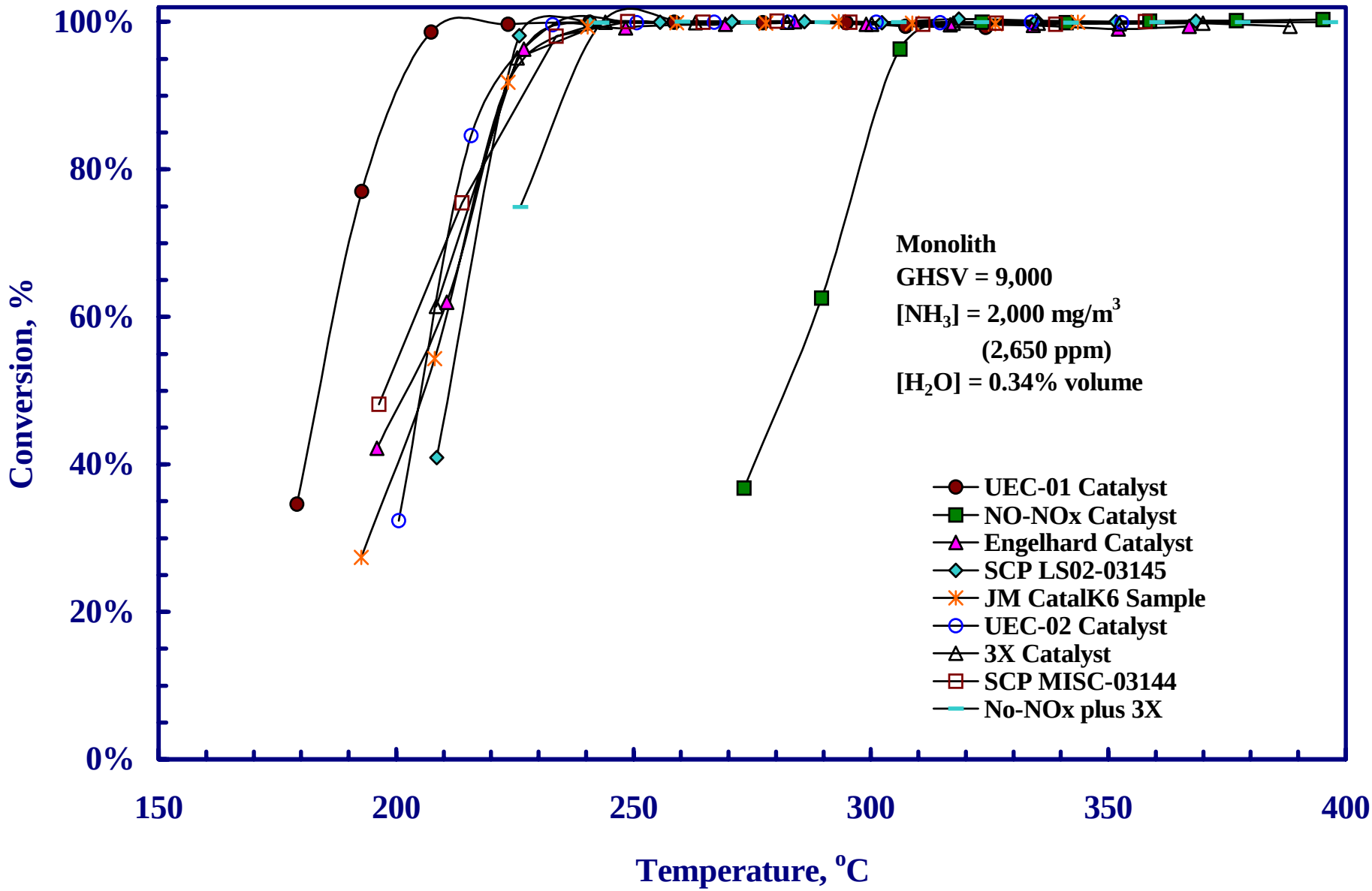
- **good indicator of catalyst activity (very clean parent and byproduct)**
- **poor effective filtration by current NBC systems**

Schematic representation of catalytic reactor



Dry NH_3 tests

Guild Associates, Inc.



Humid NH_3 tests

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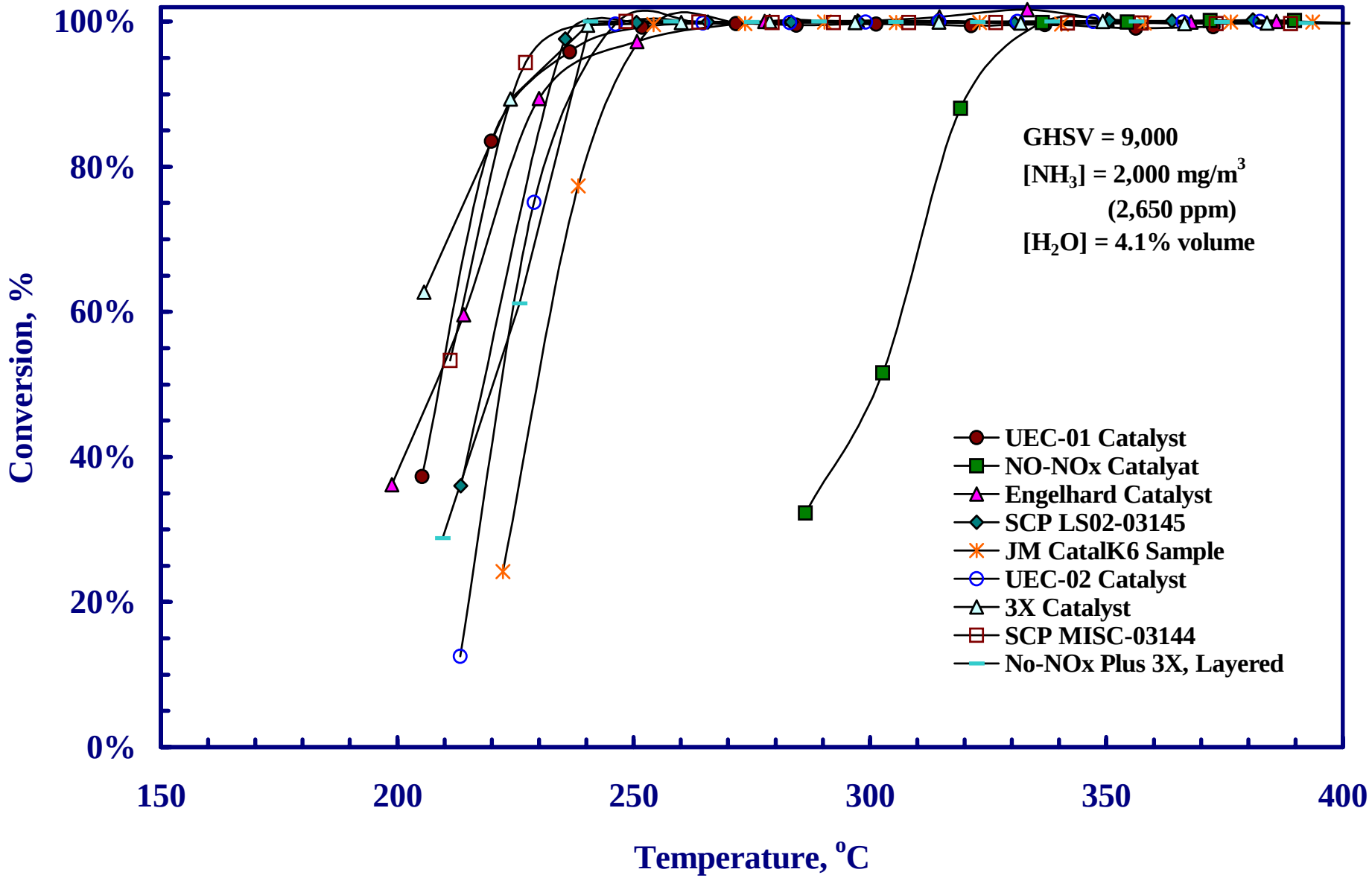
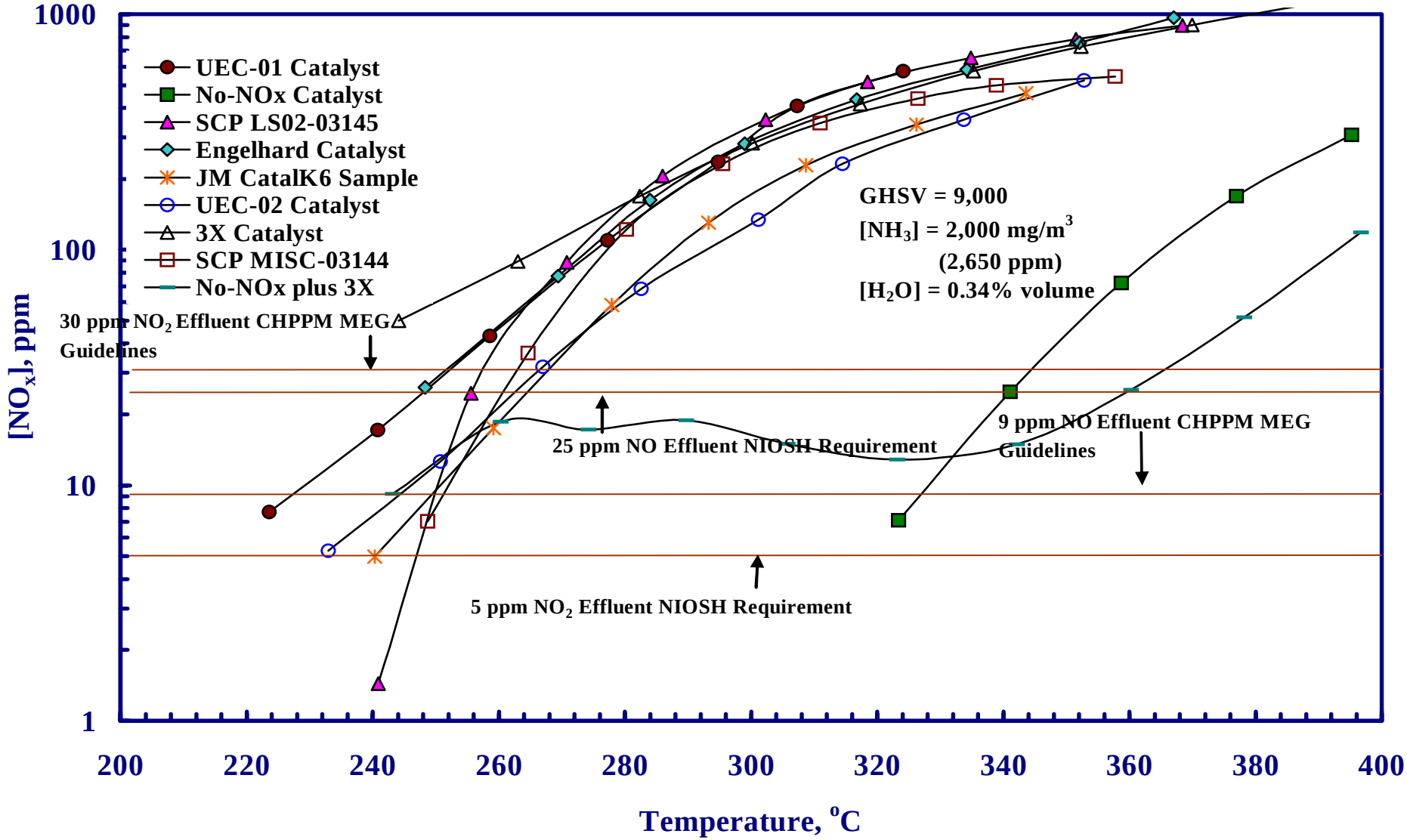
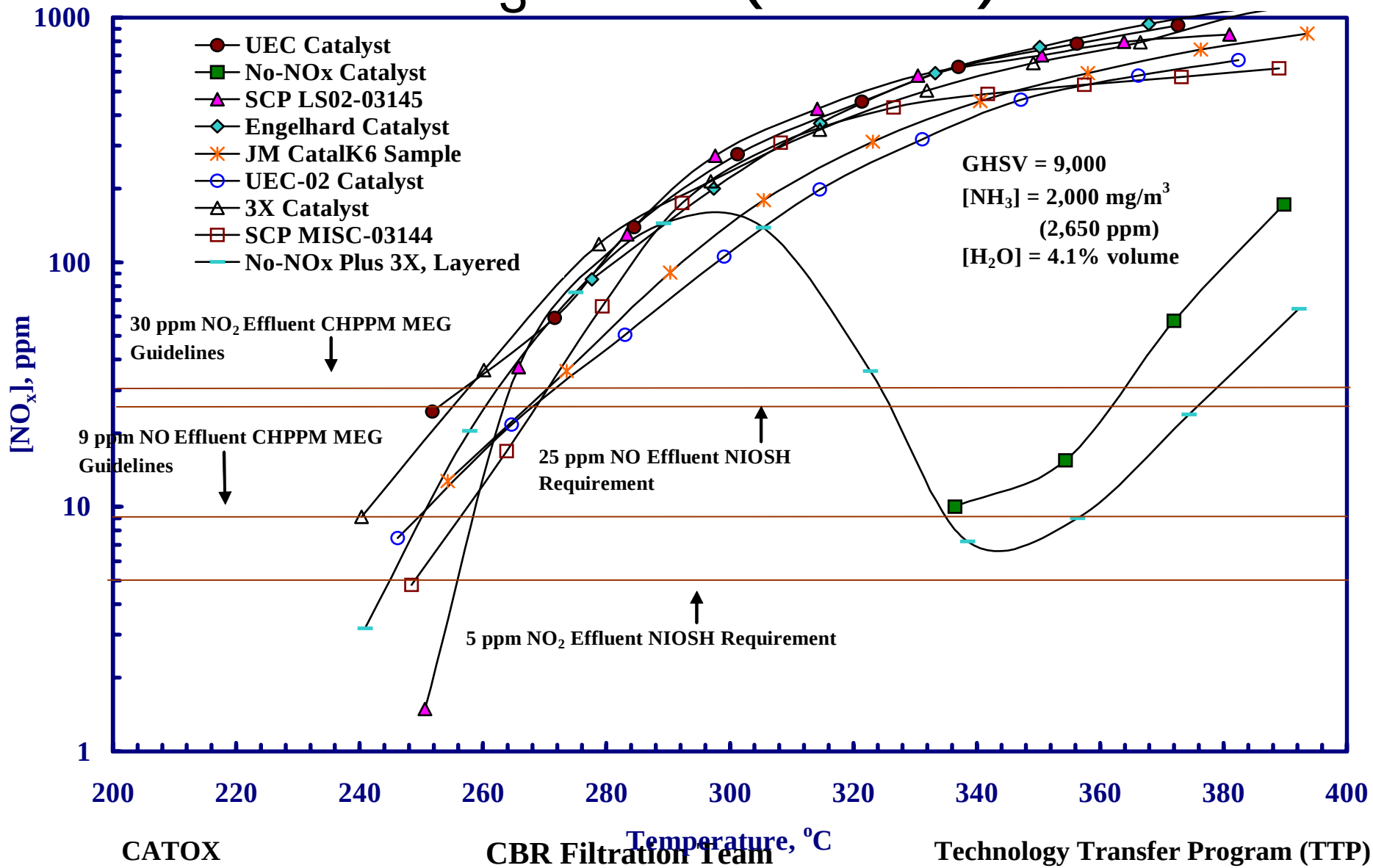


Selectivity (NO_x): NH_3 tests (dry)



Selectivity (NO_x): NH_3 tests (humid)



Selectivity (N_2O): NH_3 tests (dry)

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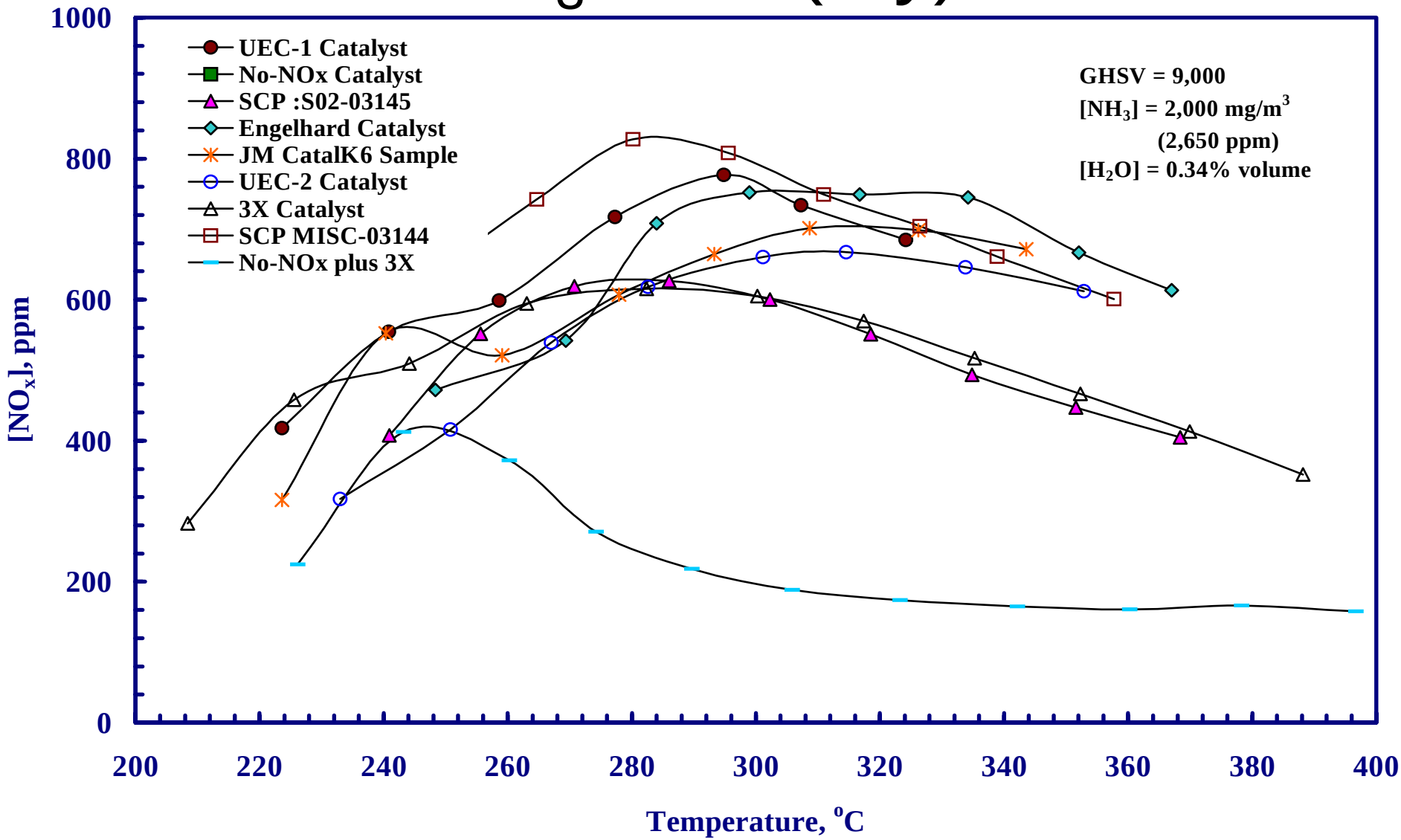
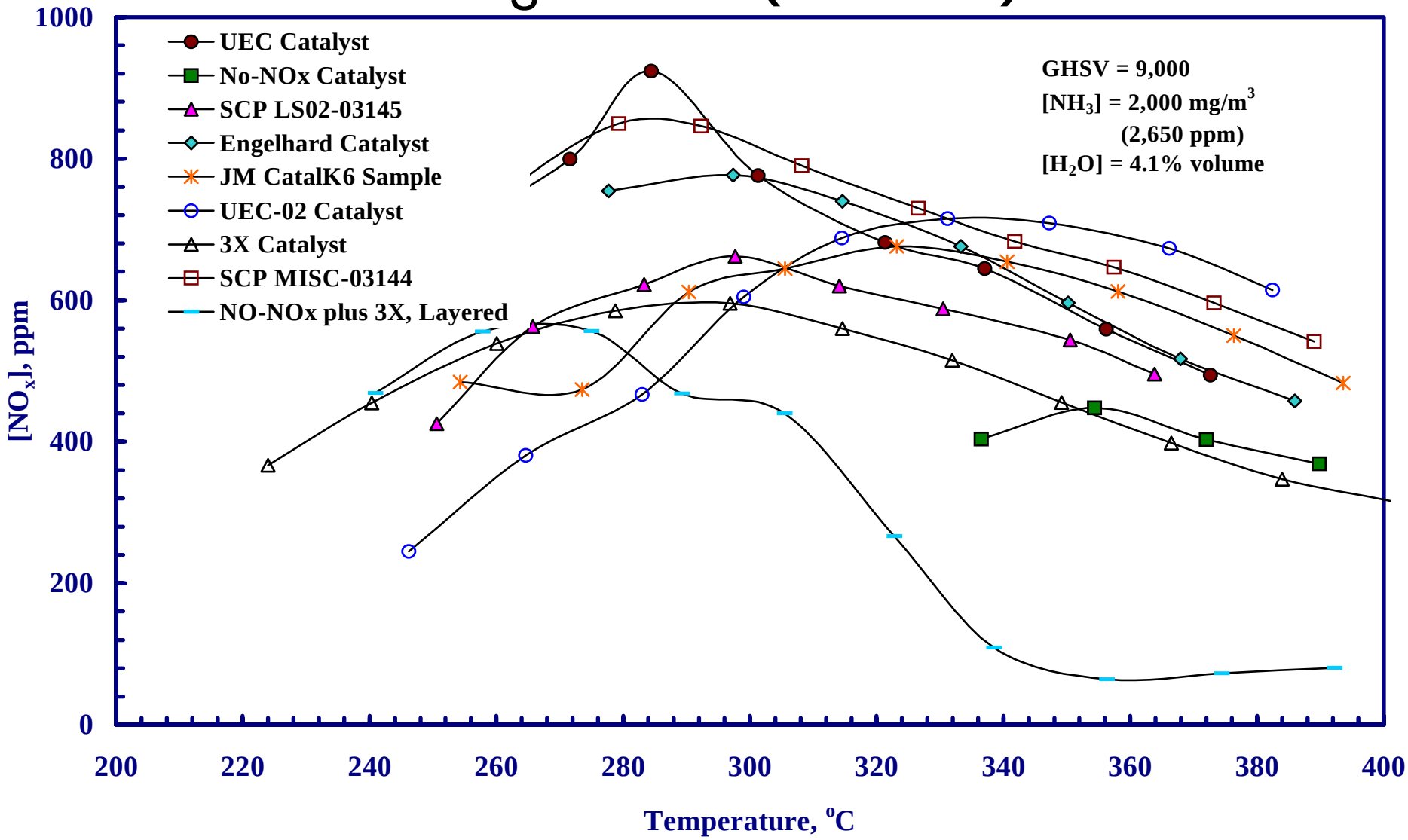
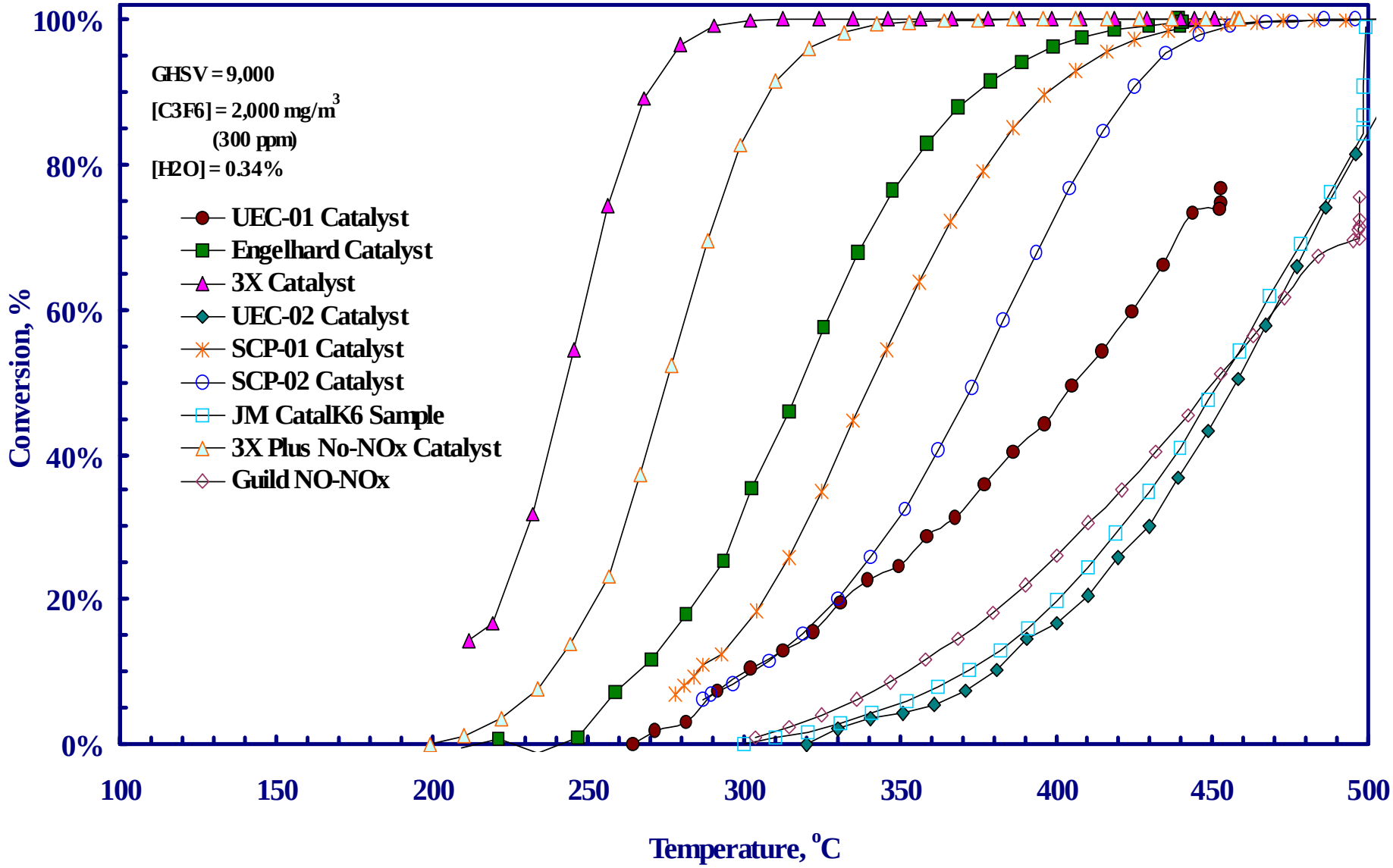


Selectivity (N_2O): NH_3 tests (humid)



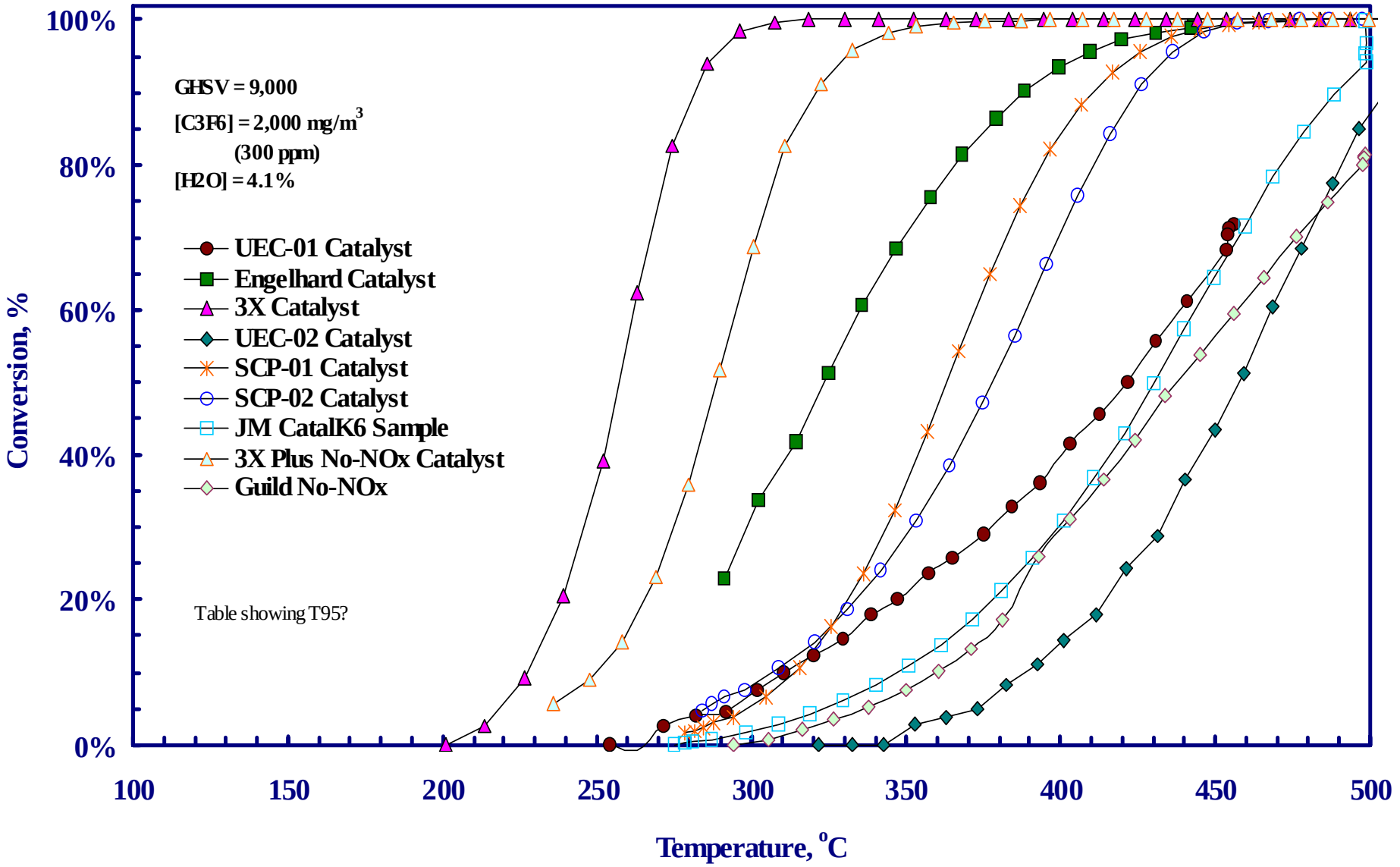
Dry C_3F_6 tests

Guild Associates, Inc.



Humid C_3F_6 tests

Guild Associates, Inc.



Catalyst Performance

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Catalyst performance summary information

Catalyst	Design Lim. Chemical[1]	Temperature[2]	Ammonia $[NO_x]$[3]	Ammonia $[N_2O]$[3]
Guild No-NO_x	C_3F_6	T > 500°C	> 500 ppm	> 300 ppm
Guild No-NO_x Plus 3X	C_3F_6	350°C	15 ppm	160 ppm
Guild 3X	C_3F_6	310°C	400 ppm	550 ppm
Engelhard #164217005	C_3F_6	440°C	> 1,000 ppm	~ 300 ppm
UEC NB001-73-001	C_3F_6	T > 500°C	> 1,000 ppm	~ 300 ppm
UEC NB001-73-002	C_3F_6	T > 500°C	> 1,000 ppm	~ 300 ppm
SCP LS02-03145	C_3F_6	450°C	> 1,000 ppm	~ 300 ppm
SCP MISC-03144	C_3F_6	450°C	> 1,000 ppm	~ 300 ppm
JM CatalyK6 Sample	C_3F_6	T > 500°C	> 1,000 ppm	~ 300 ppm

[1]Chemical requiring greatest temperature to achieve 99% destruction
[2]Temperature required to achieve 99% destruction of design limiting chemical
[3]NO_x or N_2O concentration formed during destruction of NH_3 at temperature

NBC Subsystem Summary

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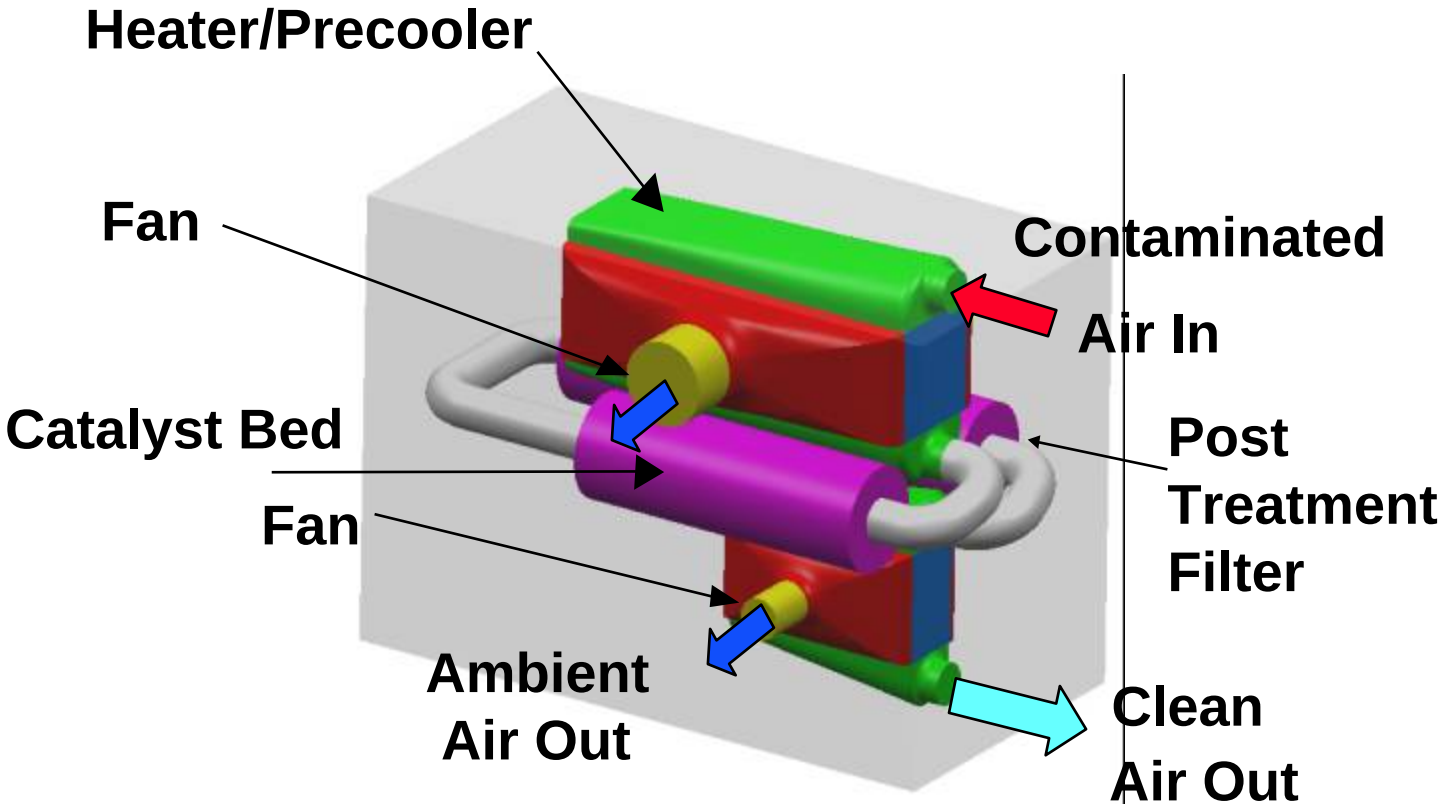


Targeted for:

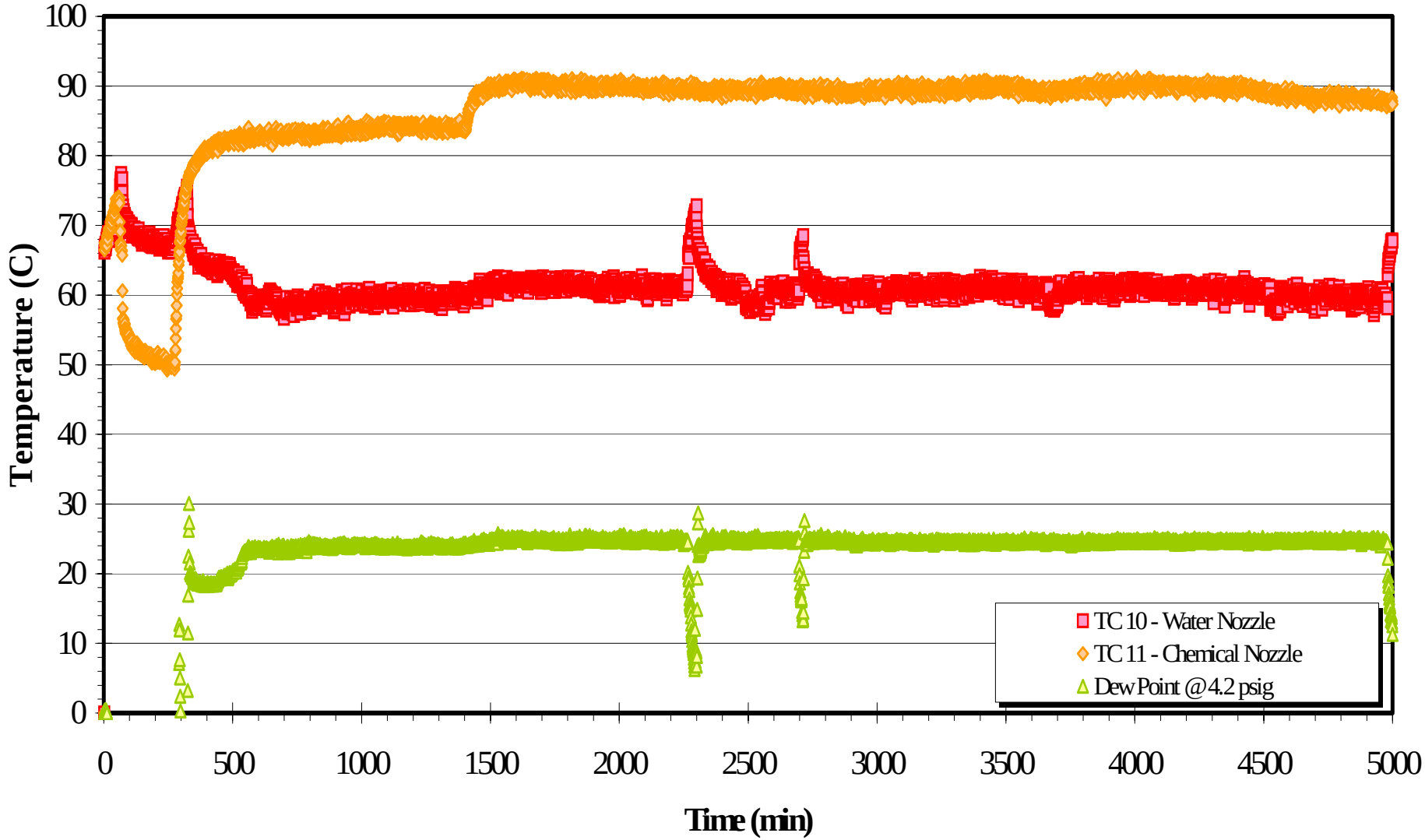
- FCS Application
- Scalable for building protection
- Transportable shelters (JECP)

Ammonia (HC): Feed Temperature

Guild Associates, Inc.

ECBC 50 SCFM CATOX UNIT

Feed Conditions



ATD Experimental Design

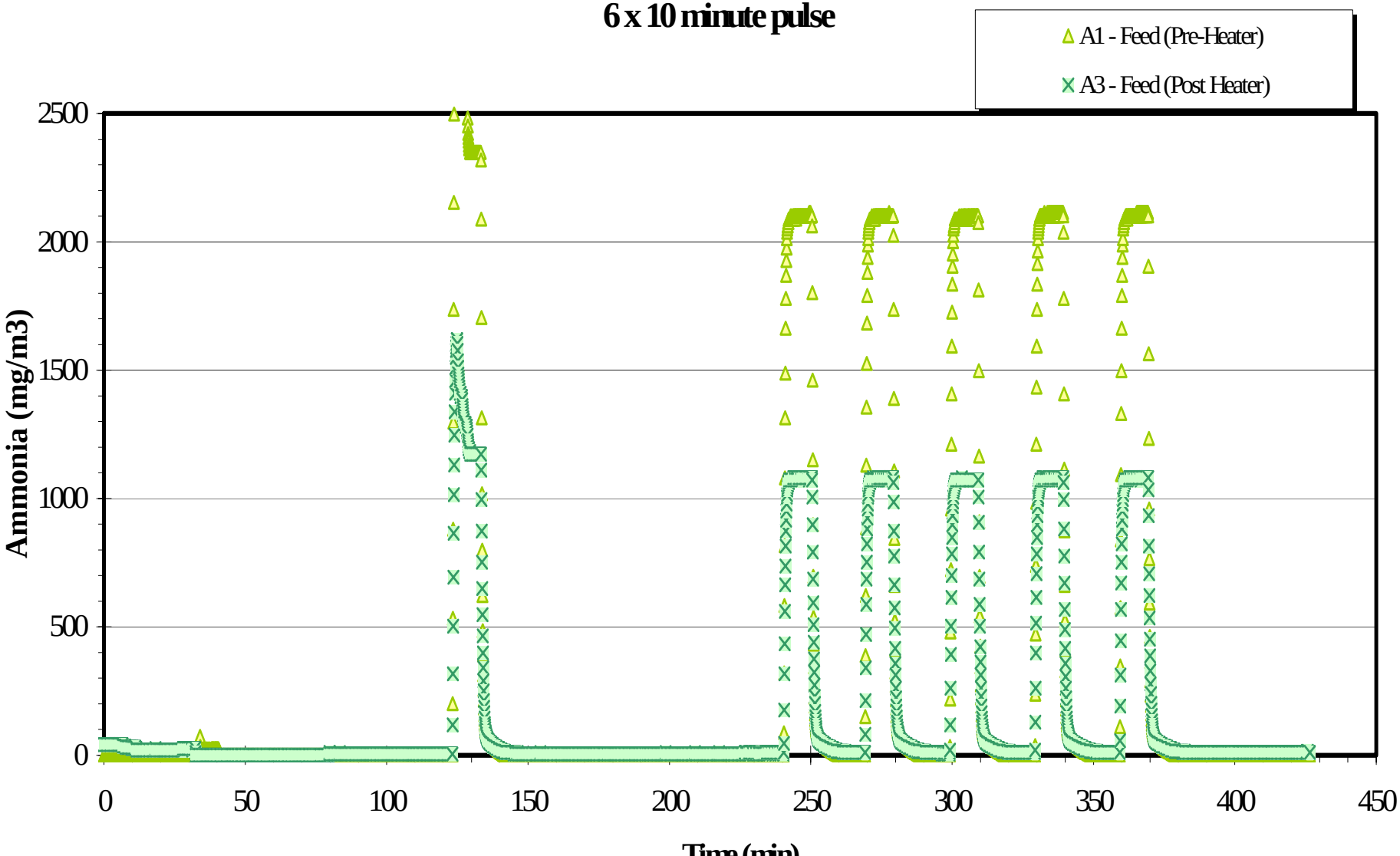
- 6 x 2000 mg/m^3 x 10 minutes
  (C_T = 120,000 mg-min/m^3)
- 6 x 200 mg/m^3 x 100 minutes
  (C_T = 120,000 mg-min/m^3)

C_T = 240,000 mg-min/m^3
(under 2.5% water (volume) and 50 cfm)

Ammonia (HC): Feed Concentrations

Guild Associates, Inc.

ECBC 50 SCFM CATOX UNIT
NH3-HW-BHc Ammonia Feed Chart 5-6-04
6 x 10 minute pulse



Ammonia (HC): Temperature

ECBC 50 SCFM CATOX UNIT

Temperature Plot

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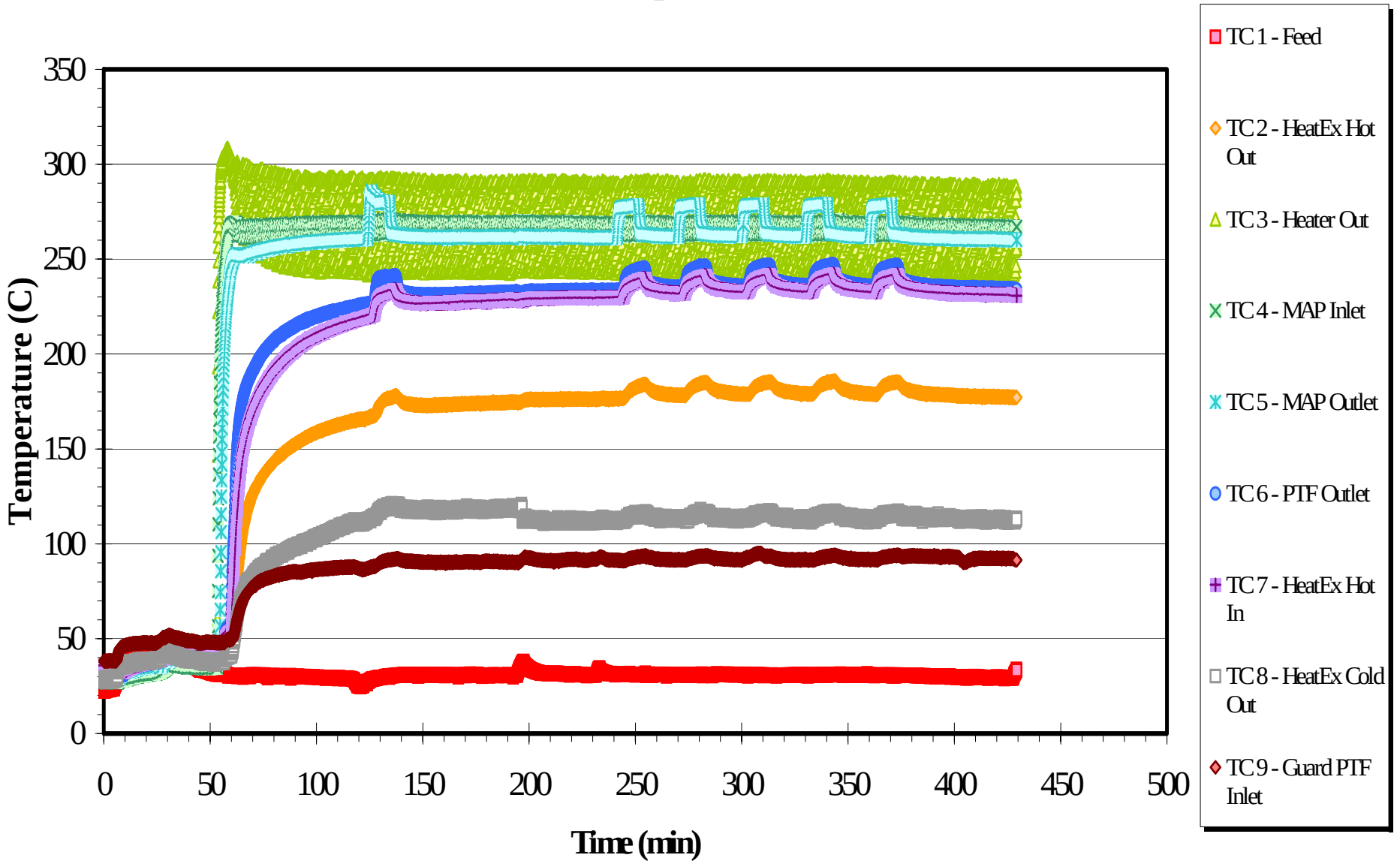

Ammonia (HC); Parent compound

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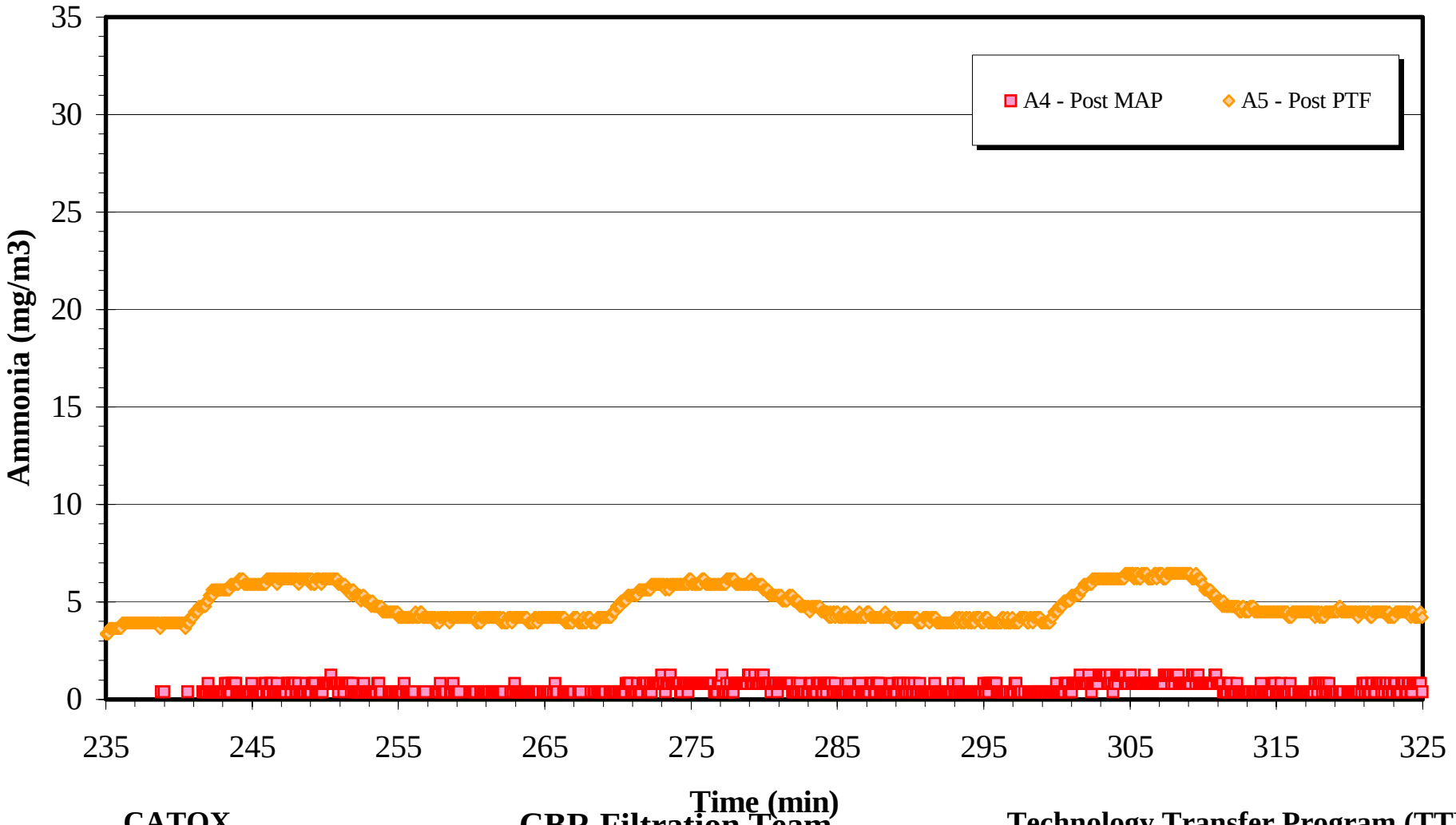
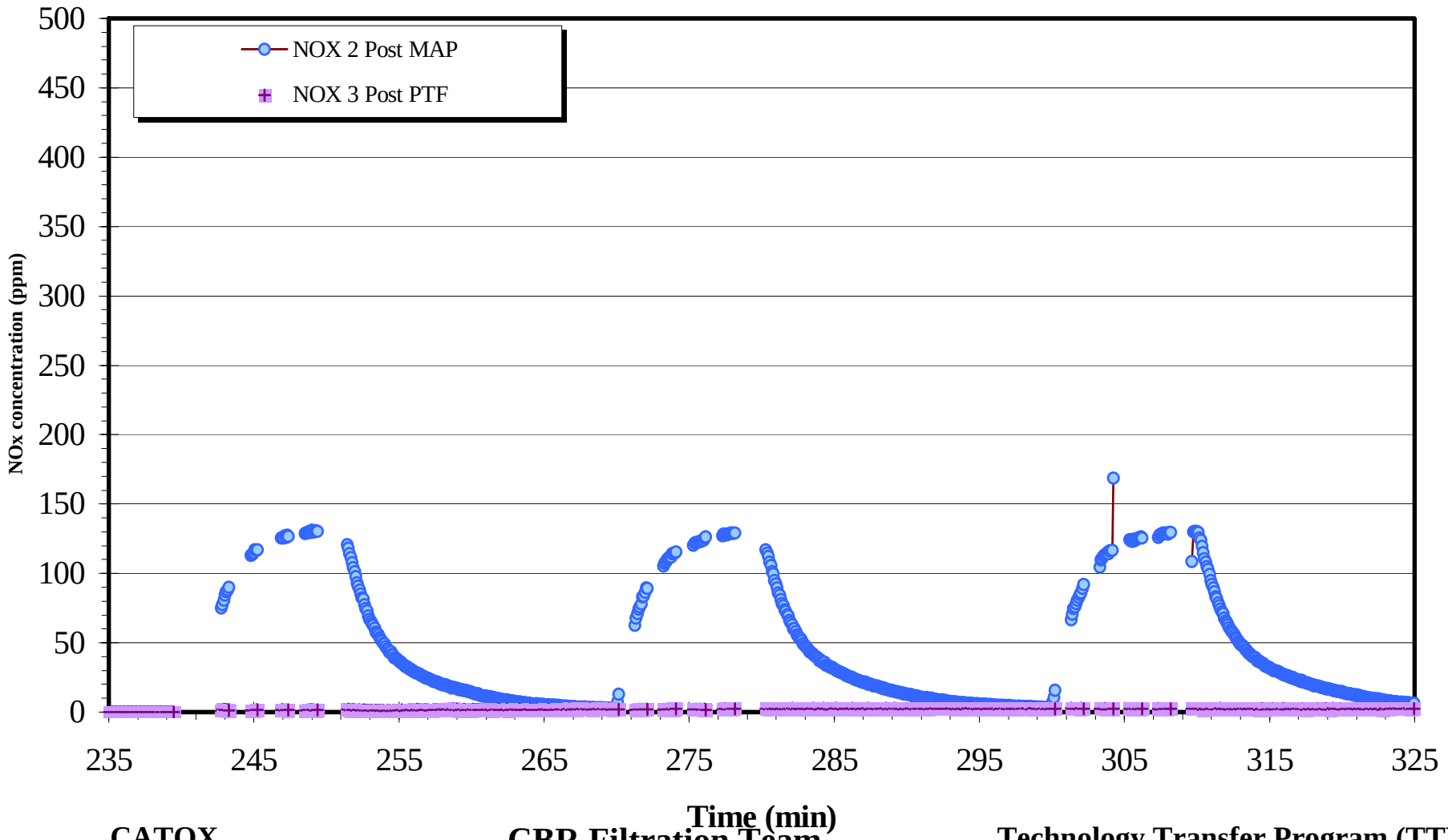
ECBC 50 SCFM CATOX UNIT
Analog Signal Chart



Ammonia (HC): By-products

ECBC 50 SCFM CATOX UNIT

Analog Signal Chart



Ammonia (LC): Feed Temperature

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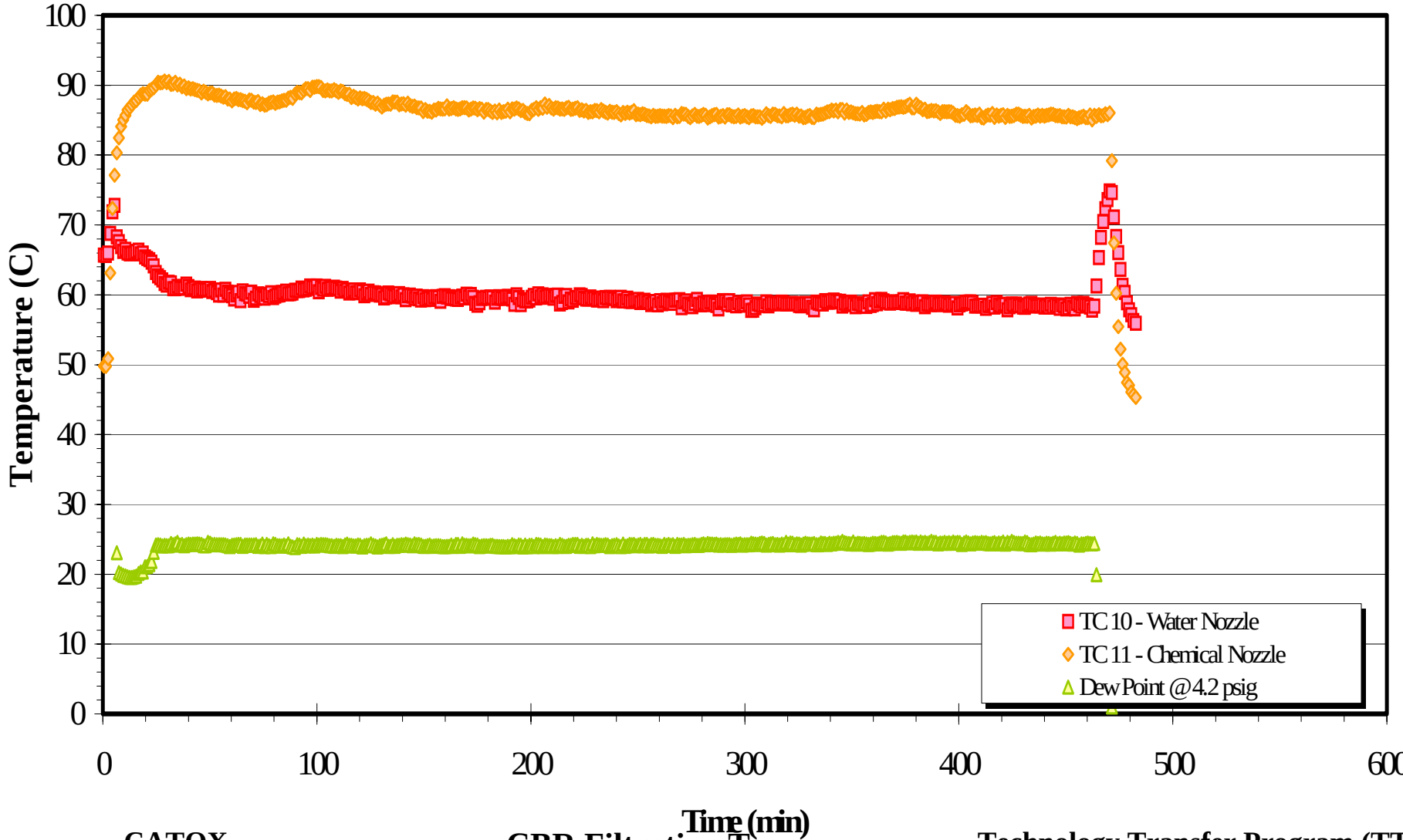
ECBC 50 SCFM CATOX UNIT

Feed Conditions



Ammonia (LC): Feed Concentrations

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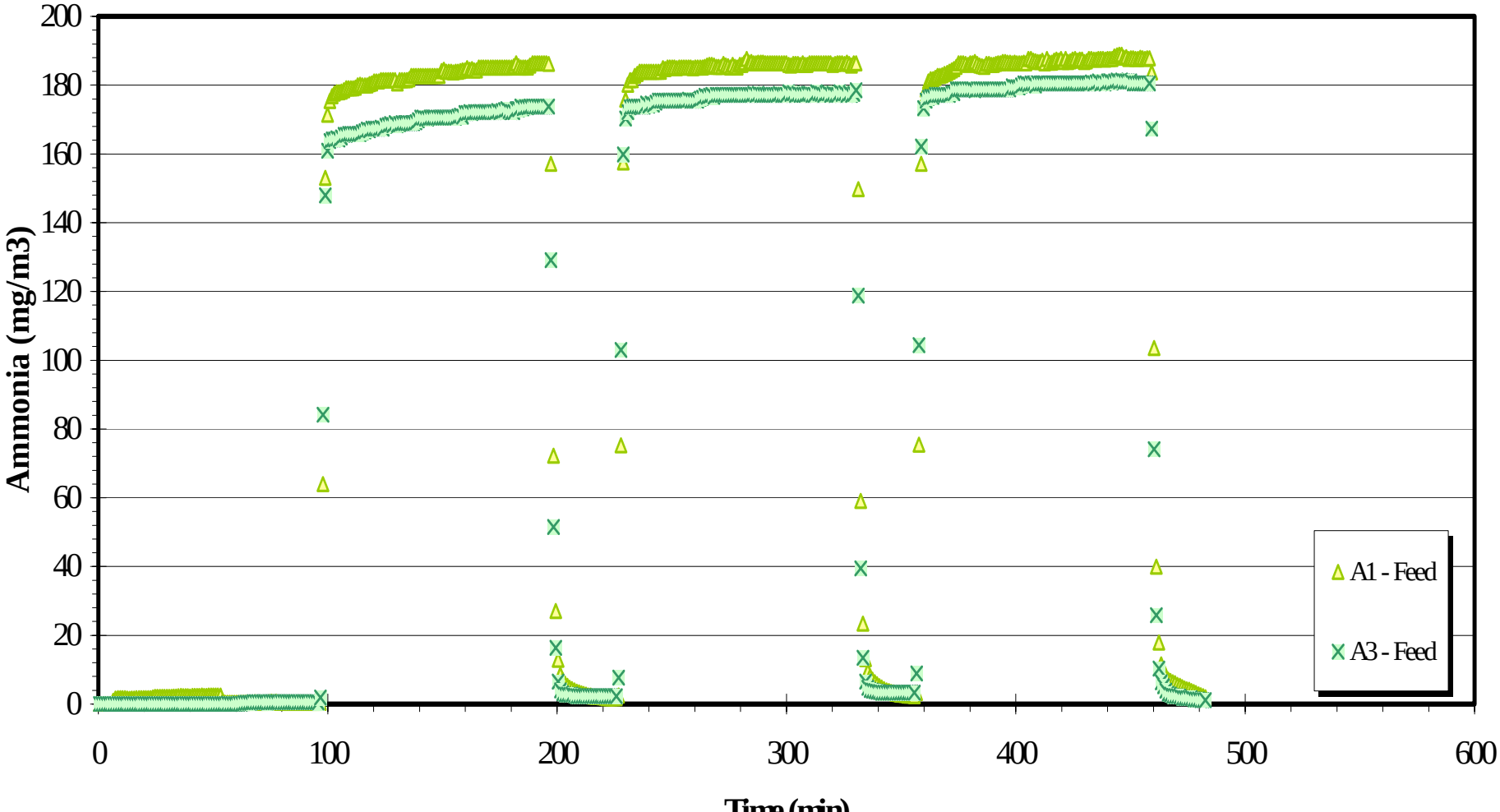
ECBC 50 SCFM CATOX UNIT
NH3-HW-BLc P3-5
Feed Chart 5-10-04

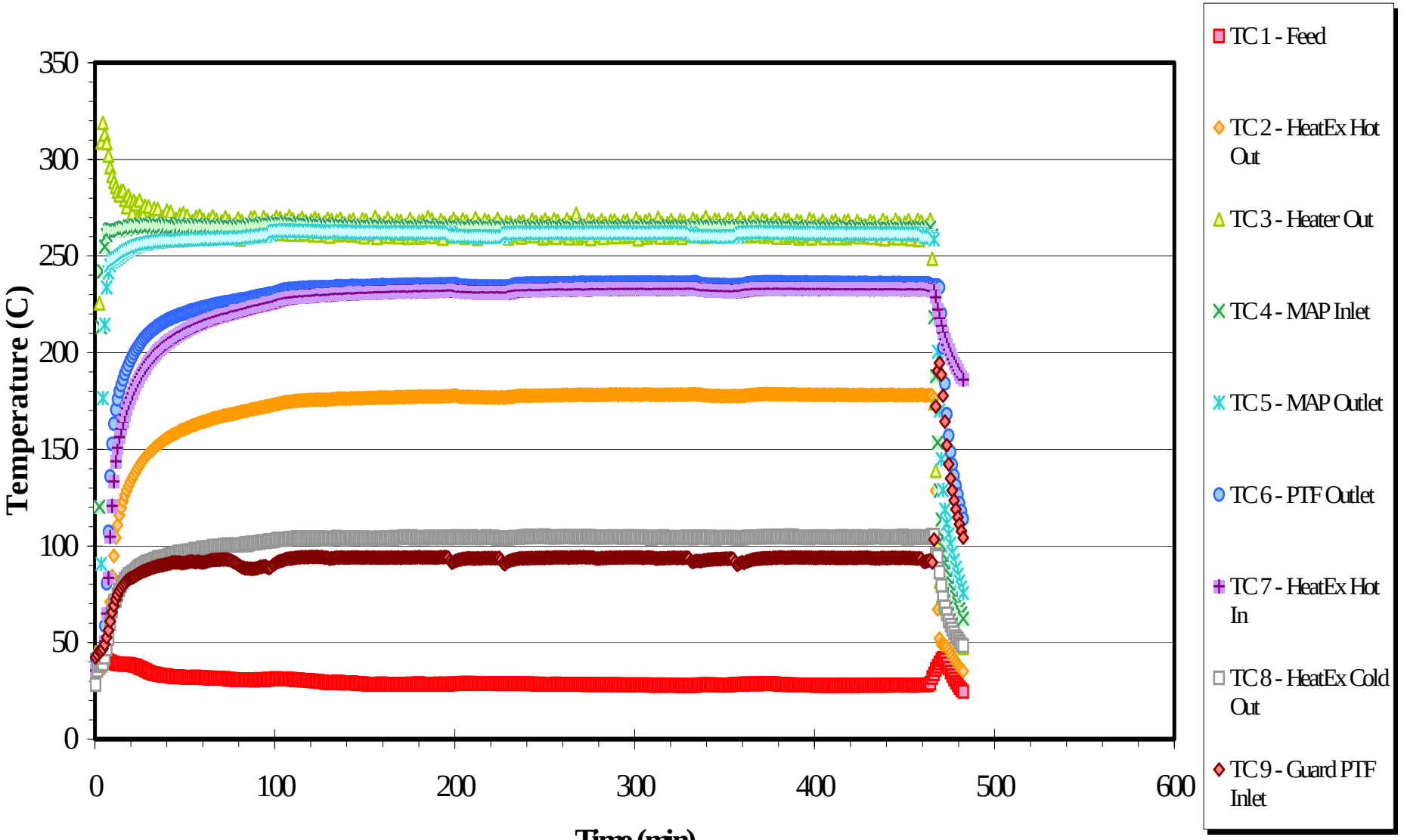


Ammonia (LC): Temperature

Guild Associates, Inc.

ECBC 50 SCFM CATOX UNIT

Temperature Plot



Ammonia (LC): Parent

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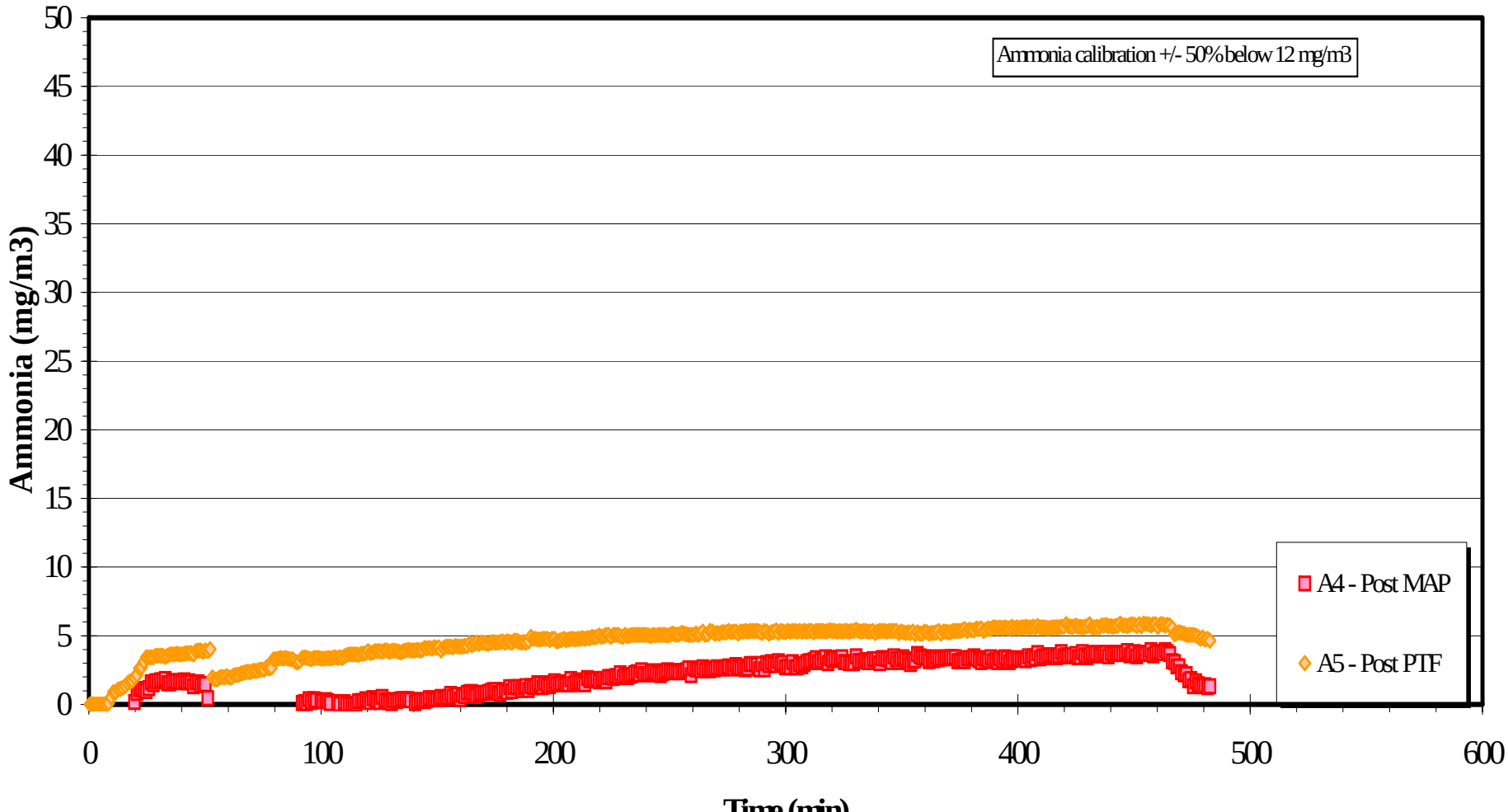
ECBC 50 SCFM CATOX UNIT

NH3-HW-BLc P3-5

Effluent Chart (NH3) 5-10-04



Ethylene Oxide (HC): Temperature

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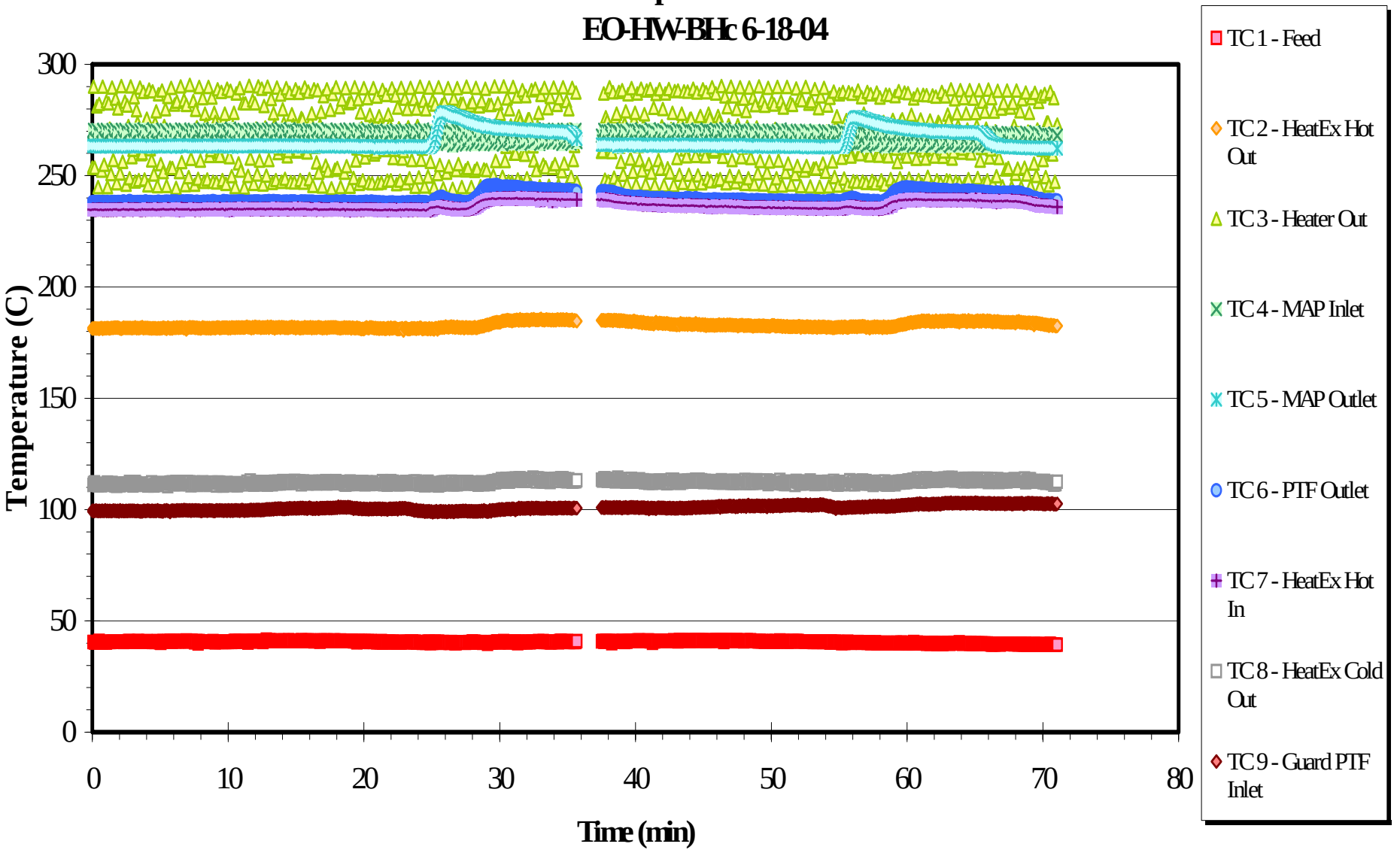


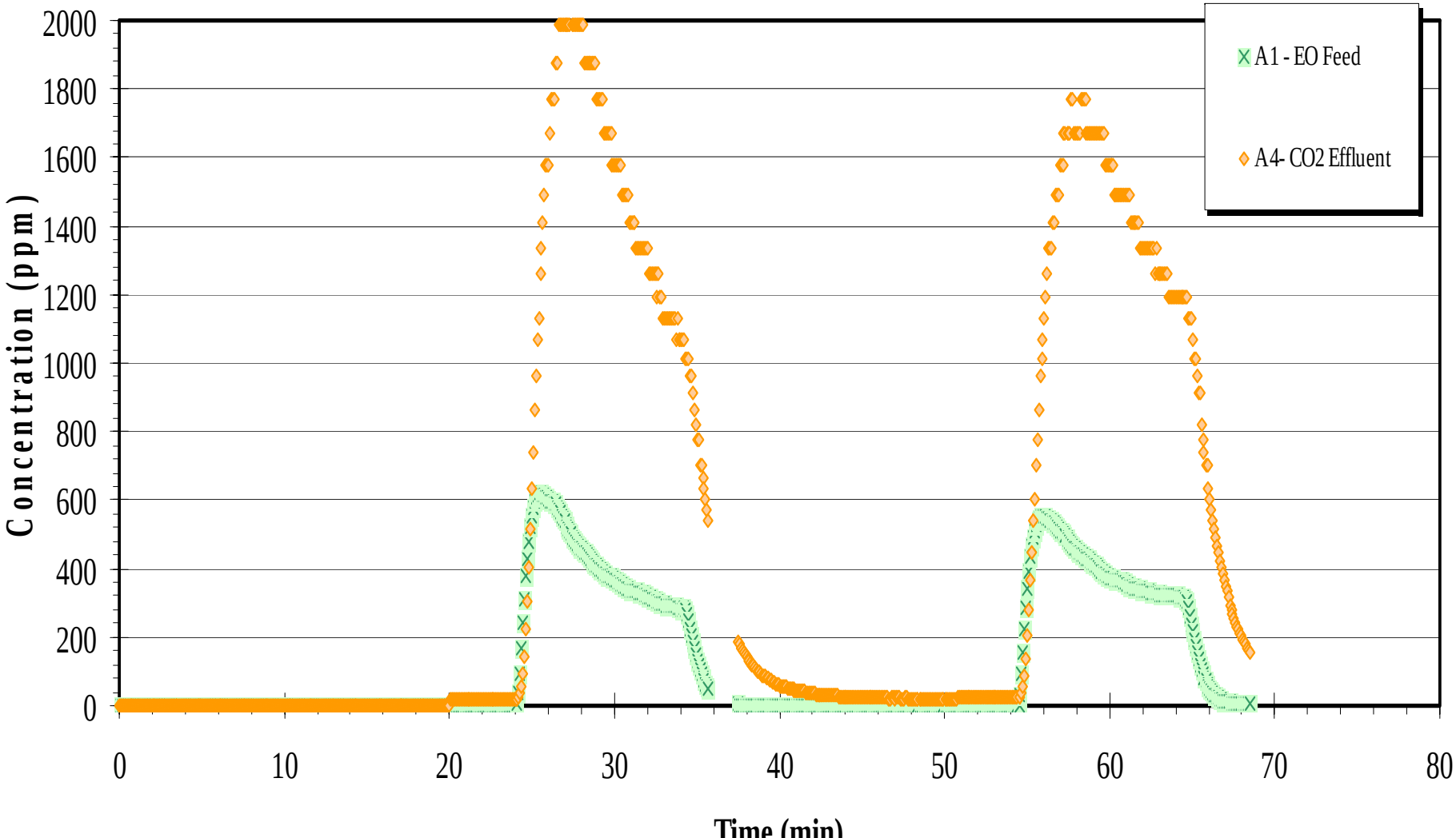
Ethylene Oxide (HC): Feed Concentrations

Guild Associates, Inc.

ECBC 50 SCFM CATOX UNIT

EO-HW-BHc 6-18-04

EO Feed - CO2 Effluent



Ethylene Oxide (HC): By-products

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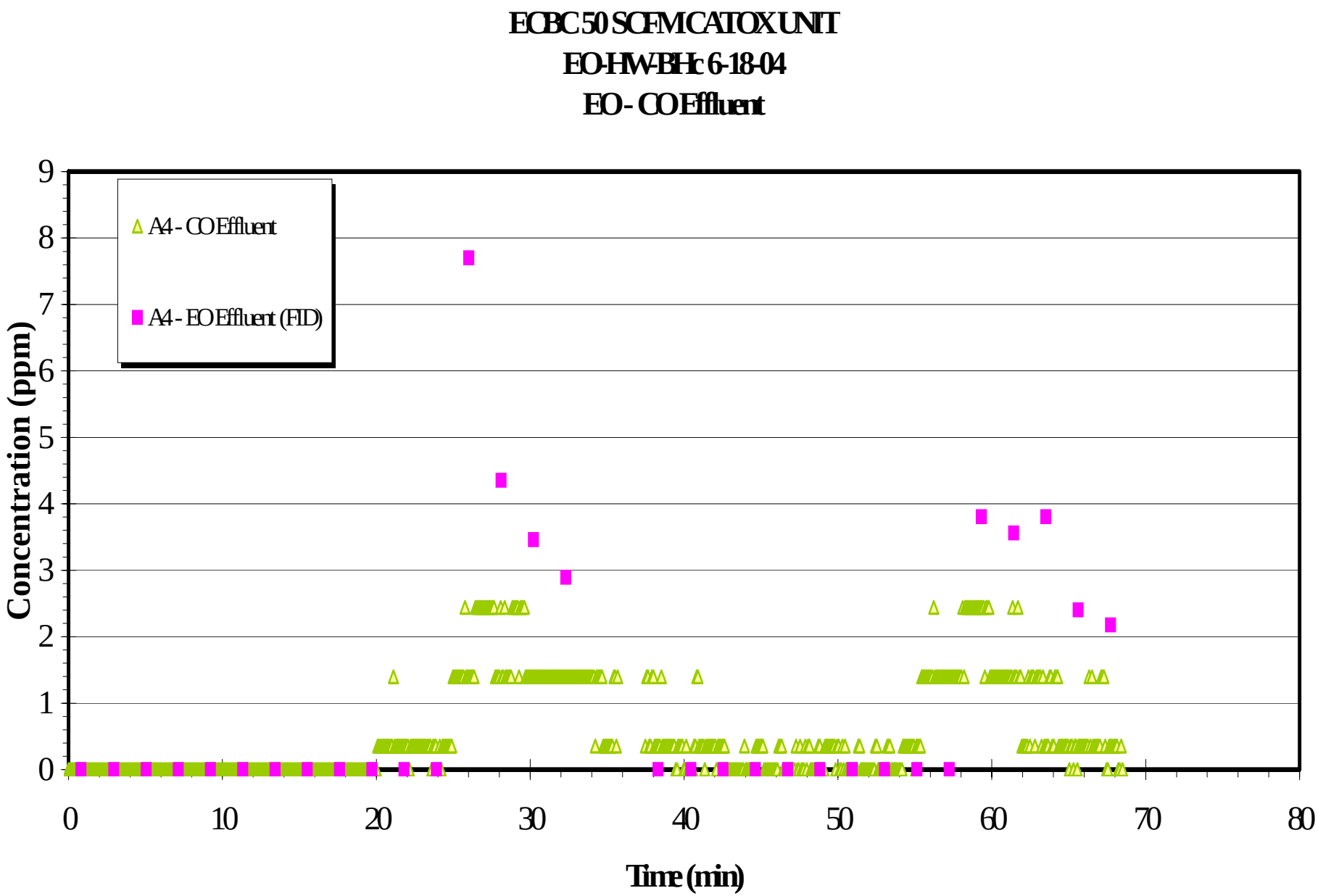
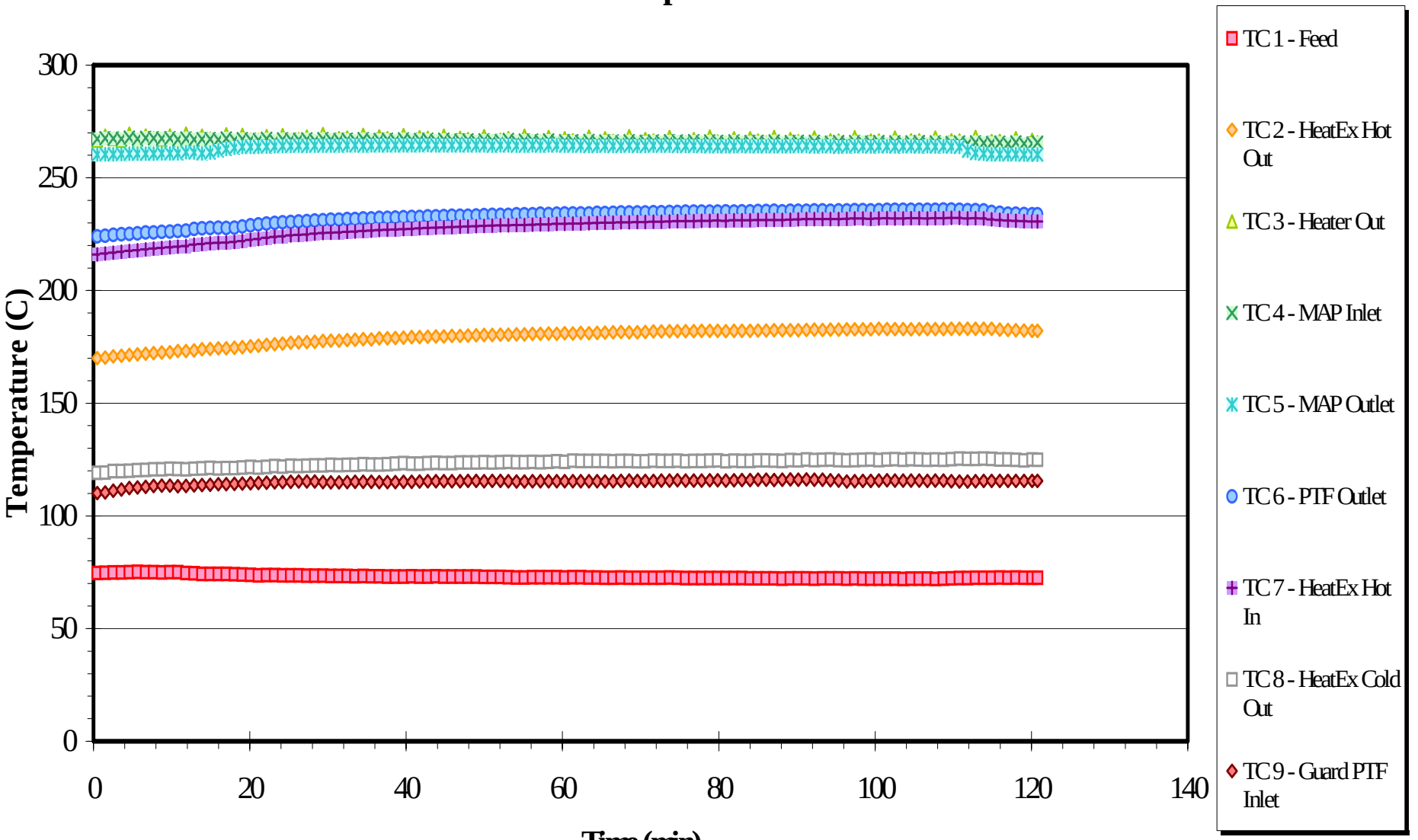


Formalin (LC)

Guild Associates, Inc.

ECBC 50 SCFM CATOX UNIT

Temperature Plot

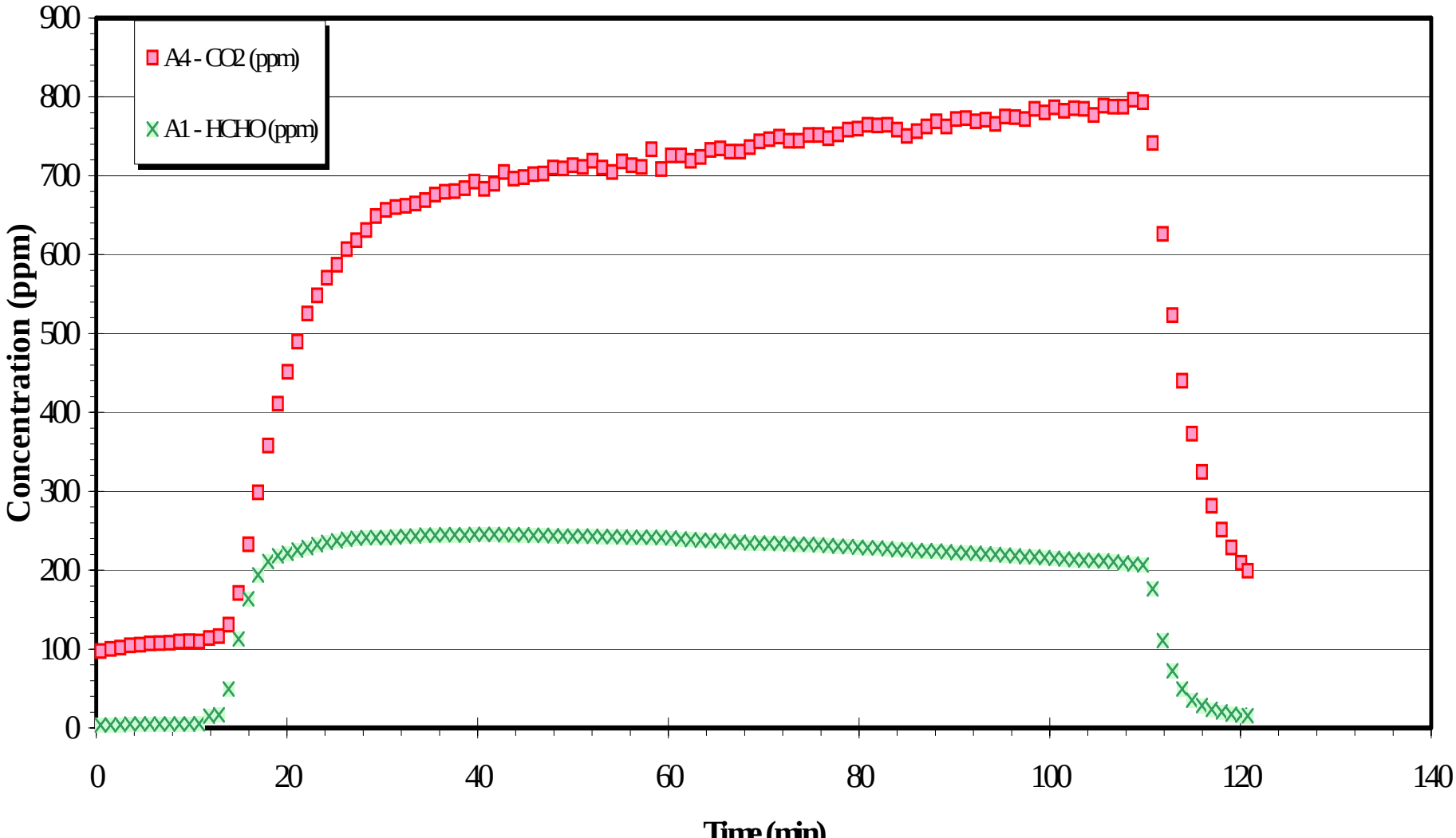


Formalin (LC)

ECBC 50 SCFM CATOX UNIT

HCHO-HW-DLc 7-14-04

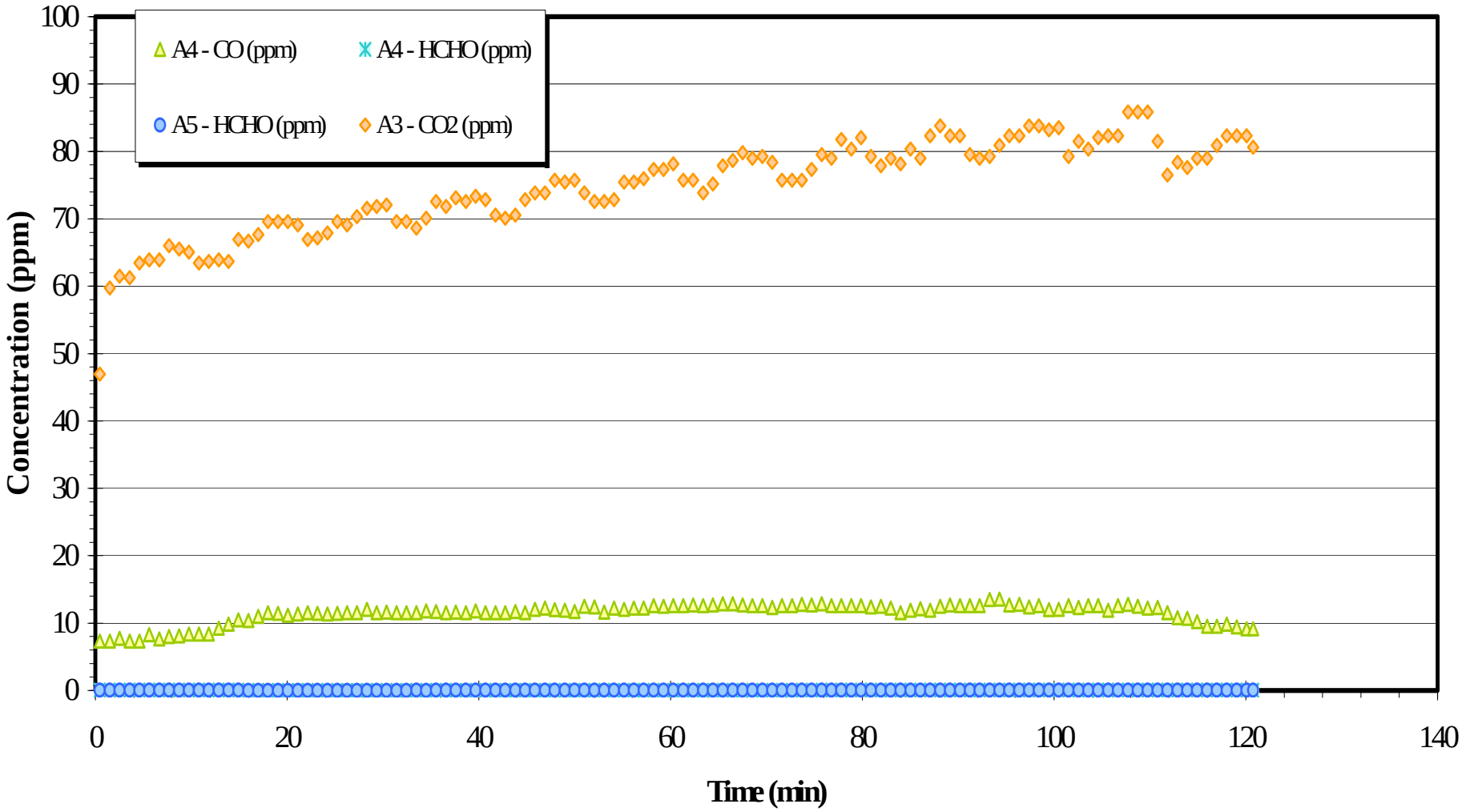
A1 - HCHO A4 - CO2



Formalin (LC)

Guild Associates, Inc.

ECBC 50 SCFM CATOX UNIT
HCHO-HW-DLc 7-14-04
A3 - CO2 A4 - CO A4 - HCHO A5 - HCHO



Guild Associates, Inc.

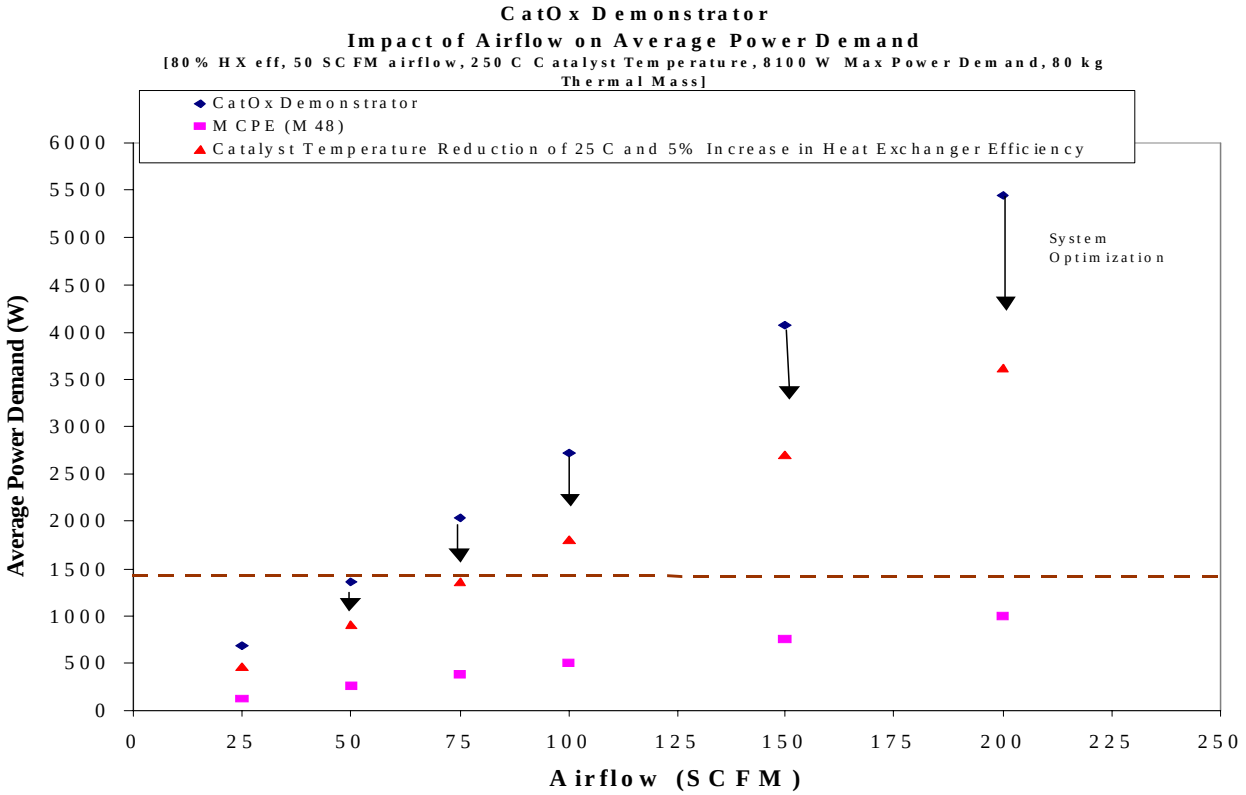
Chemicals tested:
Carbon Monoxide
Ammonia
Ethylene Oxide
Formalin
Chemical underway:
Acetonitrile
Chemicals left:
Chloroform
CK
CS2
Nitric Acid
CEES
HF
HFP
DMMP

Field conditions impacting CATOX

Guild Associates, Inc.

In a fielded system, one catalyst bed operating at one flow rate and one operating temperature will be employed.

Power and weight optimization



Improvement of Subcomponents

- Next Generation PTS
- Catalyst Improvements
- Heat Exchanger (greater 90% heat recovery efficiency
- Modular System
- Lighter, Smaller Overall Footprint

Acknowledgements

Joseph Rossin, Ph.D., Guild Associates

Russell W. Johnson, Ph.D., Honeywell, Inc.

Peter M. Michalakos, Ph.D., Honeywell, Inc.

Brian Elmiger, Honeywell, Inc.